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## A BRIEF HISTORY OF WEST GIPPSLAND

BY PHYLLIS REICHL\*

**ABSTRACT:** The region which was called West Gippsland after Count Strzelecki's journey in 1840-41 was known from the earliest period of European settlement. In 1797-98 George Bass navigated from Port Jackson, named Westernport and surveyed much of the coast. Settlement, however, remained marginal, temporary and sporadic until the period of selection which began in earnest, eastward from Dandenong along the Upper Gippsland road in the late 1860s, but not until the late 1870s in the steep forested hill terrain of the Strzeleckis. The conversion of this forest country into dairy farms was consistently fraught with difficulties and even disaster, so that by the 1930s the area of successfully settled lands had contracted everywhere to the more favourable valleys and lower hill slopes. The mountain ash country, denuded of its valuable timber cover by the pioneers, reverted to useless bracken, blackberry and regeneration scrub. The expansion of settlement in the future will undoubtedly take place in the zones of fuel exploitation and it is here, in the Latrobe Valley and along the Bass Strait coasts, that there is greatest need for research into the patterns of settlement.

### INTRODUCTION

The impact of European settlement on the natural environment of West Gippsland has been profound, and for this reason it is helpful to outline the major events of the settlement process. The region is a beautiful and fascinating one which for special reasons was opened up for occupation by Europeans later than other parts of Victoria. The present day features of the human landscape cannot compare with the great homesteads and comely towns of the Western District nor with the pleasant and interesting settlements of the belt of sustained gold mining in Central Victoria. It is easy to underestimate the scope and intensity of man's activities in Gippsland. The rare historic features give no true indication of the calibre of the pioneers of West Gippsland who expended great spirit, courage and endurance in subduing this difficult environment. Other speakers in this symposium will describe the steep and broken relief, the swamps, the coasts and above all the luxuriance of the eucalypt forests promoted by the sustained and heavy rainfall. These were the major challenges, since the complications of a hostile and resourceful indigenous population or of a dangerous fauna such as opposed the frontiersmen of the North American forests were absent. The aboriginal tribes were already in decline when effective settlement began, and in any case seem always to have avoided

heavily forested country: the native fauna, to its cost, consisted of gentle unaggressive creatures.

### EARLY HISTORY

The coasts of West Gippsland, dominated by the great embayment of Westernport and the granite projection of Wilsons Promontory were surveyed very early.

In 1797 George Bass in his whaleboat navigated from Port Jackson to Westernport naming it 'from its relative situation to every other known harbour on the coast' (from Daley 1960, p. 102). His survey of the coastline from near Kilcunda to Lang Lang Jetty, Stony Pt. to Flinders, all of French Island and most of Phillip Island, is remarkably accurate. After missing Port Phillip and Westernport in 1800, the vessel *The Lady Nelson* made a complete survey of Westernport in 1801 and seeds were planted on Churchill Island.

England was at war with Revolutionary France. One of the less publicised activities of the latter was the encouragement of scientific research. The Institute of France had promoted the well equipped scientific mission of Nicolas Baudin to Southern waters. On his return a history and atlas were published showing the whole of the Southern Australian coast from Wilsons Promontory to the Great Australian Bight as 'Terre Napoléon'.

The British, in alarm at this French threat, established the abortive settlement under Lieuten-

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ant Collins at Port Phillip to forestall any claims by the French. Certainly the latter were fully aware of the vulnerability of the British antipodean settlements and it was only Nelson's victory at Trafalgar in 1805 which removed the French menace to these coasts. Again in 1824 the exploring vessel *L'Astrolabe* under D'Urville re-awakened the old fears.

As a precaution a settlement was established under Captain Wright, not far from Corinella on Westernport. In the meantime, sealers and whalers from Tasmania, often ruthless and desperate men, were operating from small primitive villages in safe sheltered harbours like Westernport and the east coast of Wilsons Promontory. By 1830 they had exterminated the sea elephants and decimated the seal population. In the season they collected wattle bark. Thus their activities were purely predatory. Once again fear of the French subsided, the little settlement at Corinella was abandoned and Westernport deserted.

### PASTORAL HOLDINGS

The establishment of the Port Phillip settlement and its recognition by Sydney promoted the opening up of grazing country out from Port Phillip at Dandenong, Cranbourne and Westernport. Eastern progress was blocked by dense and apparently interminable forests covering the country below the ranges and by a succession of treacherous swamps heavily covered with an almost impenetrable thicket of tea tree and rotting vegetation. In far east Gippsland beyond the Strzeleckis, the pastoral holdings were already established following Angus McMillan's epic journey from Monaro in 1838-41. The wreck of the *Clonmel* running mails between Sydney and Melbourne occurred at Port Albert in 1841. The resulting rescue and investigation operations opened the sea entry at this point to the settled eastern lands and this partly removed the necessity to find a land link between eastern Gippsland and Port Phillip. Count Strzelecki's expedition in 1840-41 had this aim, but appalling experiences in the great forest confirmed the impracticability of the route. When he finally won through to Westernport Strzelecki found a string of stations from Anderson's and Massey's on the Bass River to Robert Jamieson's at Tooradin. Cranbourne was 'a small place with several wattle and daub buildings with thatched roofs' and Dandenong 'a nice little village' (Daley 1960, p. 105).

Timber getters were opening up the red gum country round Dandenong, providing paving blocks and wharf planking for Melbourne. Dunbar's Hotel was their meeting place and also served

as the Roads Board and Council Chamber, the Church and the Court house.

Eastward lay Berwick where Captain Gardner had his run and where the township was surveyed in 1852. At first the farms grew potatoes and wheat for Melbourne and the diggings, later switching to dairying, cheese making and sheep.

In reality the pastoral holdings lay only round the fringes of the great forests, though on paper they extended over the whole of West Gippsland. Matthew Gibson for instance held the Wild Cattle Run, named after progeny of the cattle abandoned from the Corinella 1826 settlement. This run had an estimated 256,000 acres with a carrying capacity of 640 head of cattle.

Over all Victoria the 1850s saw the formation of Roads Boards, the forerunners of municipal bodies. Mail and coaching services were established and blacksmiths, wheelwrights, saddlers, boat-makers, bakers and builders moved out from Melbourne to the embryonic settlements serving the gold mining and selection areas. This brings us to the crux of the problem of penetrating the difficult country of West Gippsland, the opening up of the tracks.

### TRACKS INTO THE FOREST

As early as 1847 a horse track had been established from Dandenong through Berwick to Bunyip and on to Flooding Creek (Sale). Mrs. Perry, the indomitable wife of Bishop Perry, has left us a graphic account of this track when they journeyed over it in 1849. A few years later the Surveyor General decided to make a direct road through from Melbourne to Sale, and although steep gullies between Bunyip and Moe presented great difficulties, the coach road finally became available in 1865, eight years after the letting of the first contract in 1857. Stimulated by the gold discoveries at Walhalla, the settlements along this route flourished to the detriment of those on the Port Albert route (the Lower Gippsland Road).

Further south and running almost parallel, McDonald's track from Lang Lang to Morwell followed the less densely forested northern slopes of the Strzeleckis, having been surveyed in 1862 as a stock route from Sale. Unused for this purpose, it became the jumping-off place for selectors in the great forest. One of the first of these was James Baker who established his farm on the track just east of Lang Lang (then Tobin Yallock) in 1866. He became a legend of hospitality, helping selectors on their way in the great wave of settlement beginning in 1875. His story is interesting.

In 1852 he married Miss Dorcas Stephens in Gloucestershire (England). They embarked on



the bark *Old Early Grey* on Christmas Eve 1852. On May 4, 1853, Doreas gave birth to their first child; she landed in Victoria on May 6 and on May 8 went to work for Mr. Samuel Griffiths near Hobson's Bay for three months! Later husband and wife worked on the land they selected at Lang Lang. From there James wrote to the government in 1887 petitioning for fifteen acres of land for a cemetery, which was granted and—I quote James—‘I had the pleasure of digging the first grave and read the first burial service’ (James Baker in *Land of the Lyre Bird*, 1960, p. 381).

And so we come to the epic of the settlement of the great forest of the Strzeleckis. Eastward from Melbourne lay the belt of red gum forest, then on the foot hills open messmate and peppermints. In the west Strzeleckis, lower and less steep than in the east, blue gum formed the canopy with an intermediate storey of blackwood, hazel musk and wattles and as ground cover a thickly matted undergrowth of swordgrass and wire grass. Creepers, tecoma and wild clematis linked the forest layers together. The 1851 bushfires had burnt through these forests so that a good deal of this was regeneration forest by 1875. Further east on the higher Strzeleckis the mountain ash forests with their high humidity had excluded the fires and were in their virgin state when attacked by the settlers.

## SELECTORS

Those who came in and were successful left a remarkable record of their activities, coherent, detailed, vivid as though they knew that they were engaged in an operation of historic moment. (See *Pioneers of Gippsland* 1920, subsequently *The Land of the Lyre Bird* 1960). They were only rarely farmers and most were from quite unrelated callings, schoolmasters, seamen, newspapermen, wheelwrights, warehousemen and one tea-planter. The motives driving them to their here-ulean tasks were ill defined: certainly the old deep seated lust for land, certainly the economic recession of the colonial seventies. Some of them, after experiencing years of heat and drought in North Victoria were attracted by the temperate climate and plentiful rain of Gippsland. They all shared the common misapprehension that abundant vegetation equated with fertile soil, being of course quite ignorant of ecological balance and of the consequences of stripping forest from steep slopes. In addition to these successful ones were the unrecorded numbers who succumbed to the difficulties of living for years on their capital, of battling with the plagues of caterpillars and forest regrowth, disheartened by the rain-sodden trackways which were rivers of mud and by the econo-

mic problems of no markets for their products and of collapsing land prices at the end of the land boom. They came from all parts of Victoria, many from the Ballarat region, from Horsham, Geelong, Kerang, Melbourne, a few from Britain, some from New Zealand. They journeyed from the Albion Hotel in Bourke Street by coach to Lang Lang, and then, refreshed at Jimmy Bakers, walked up McDonald's Track to peg their selection. I quote (T. J. Coverdale in *The Land of the Lyre Bird* 1960, p. 106).

‘It started almost at once, a dense mass of hazel and tall thick swordgrass. Entering this we saw a dark, narrow tunnel, seven feet wide, through which ran a canal of mud—the mousehole. Things did not seem a bit cheerful for the scrub looked dark and gloomy in that winter's afternoon.’

Their selections were 320 acres,  $\frac{1}{2}$  a square mile, in itself an uneconomic unit, too much for one man and his family, enslaving him in the burden of clearing, sowing for grass, and fencing. Understocked, the land rapidly reverted to forest. Stocked to capacity, there was no accessible market for milk or meat. Many of them were impressed with the beauty of the forest but only rarely are they sensitive to the pity of its destruction.

‘No matter in which direction I looked all was the most astonishing and bewildering forest. The majestic tall trees of the extensive eucalyptus family with their clean cut poles towered aloft in the clear blue sky. They were surrounded with a wealth of beautiful undergrowth in which blackwood, musk, hazel and blanketwood mingled with the magnificent tree ferns. . . . In the midst of such a harmonious scene of beauty, I forgot for a time the stern necessity of my presence in this enchanting Eden’ (W. McKenzic McHarg in *The Land of the Lyre Bird* 1960, p. 327). But alas today there only remains the vivid recollection of it all.

Others came in by the new railway completed to Sale in 1879, as far as Drouin, then up the old coach road. From the point later to become Poowong, McDonalds track crossed the Lang Lang river and where Horsley's or Holmes's or Scott's hotels offered comfort in the wilderness, tracks fanned out in all directions south-east along Whitelaw's track, south-west to Grantville, south to Inverloch. A few came in by boat to Grantville, and another group penetrated from Morwell along the Tarwin Valley.

The men came in first with an axe, a box of matches and a bag of provisions. Dressed in moleskin trousers, nailed boots, flannel undershirt and cotton overshirt, cabbage tree hat, they laboured incredibly to fell the trees, to burn, to pick up, to sow grass so that the animals could be brought in. They slept in tents, in rolls of bark,

in hollow logs. Bachelor housekeeping in the bush was not without its pitfalls and there are refreshing tales of boyish larks, trouble with washing, with breadmaking.

'As it was in the garden of Eden so it was here. Man came first and woman later.' (Mrs. W. J. Williams in *The Land of the Lyre Bird* 1960, p. 348-349). But here is the pioneer woman with her seven weeks old baby. 'We mounted our horses and proceeded to Kongwak... At last we came to what was supposed to be a clearing on top of a very high hill from which we could look down on the tops of the trees all round, except the narrow ridge where we came out, and on a ledge, some 200 ft. below, my husband pointed to what appeared to be some galvanized iron on top of a pile of logs and said, 'There is your home'. At first I could not speak and my eyes filled with tears. That one spot of iron in the midst of a sea of logs and stumps looked so desolate that my heart failed me for the moment.' And so she stayed, to bear her children, cook, wash, sew, nurse, isolated from the rest of her sex in a little enclosed cell of the forest. 'Oh how I used to love the early morning when everything awoke to new life. I would just stand and feast on the beauty and glory of it all.' (Mrs. W. J. Williams, loc. cit.)

Inevitably the forest had its tragic and macabre episodes, lonely deaths of women, violent deaths of men and the sad fatalistically accepted infant mortality far from any hope of medical care. But the decencies were observed. Jimmy Baker was not the only layman to read the burial service.

## GROWTH OF SETTLEMENTS

The little settlements grew, following closely the lines of the tracks. Poowong at the nodal point of all the tracks acquired its name. South of McDonald's track was Jeetho parish. North was Poowong parish. In the staunchly democratic manner of the times a meeting was called to decide the name between Jeetho and Poowong. South of the track were the church and the store. North of the track was the public house. An old Scot settled the issue. "Jeetho indeed! A gospel shop and a paltry tin pot store. I'll vote for Poowong!" (W. H. C. Holmes in *The Land of the Lyre Bird* 1960, p. 162).

They built their own schools, churches and athenaeum. The banks came in, the post office was established and the police station. Butter began to sell. The South Gippsland railway was completed in 1892 liberating them from the glutinous tracks. Timber mills were started and coal mines in the south around Outtrim, Korumburra and Jumbunna. All this development meant

the growth of towns, a market for their produce and greater mobility. A second wave of settlers had started to come in, in the late 1880s. The cells in the forest grew larger, the settlements moved closer together. The winds blew through, drying winds.

And in 1898 came the appalling reckoning—Nature's backlash. At the end of January, culminating on February 1st, Gippsland was savaged from end to end by repeated waves of bushfires, springing from neglected burns. At the end of the disastrous week, forest, homes, paddocks, fences, stock were incinerated.

'By the settlers themselves that strenuous week will never be forgotten. The long battle with the fires, the anxiety and crushing disaster in the end with its consequent worries, aged many of them more than the years of hard work. It was a cruel setback to them after all the years of struggling and tardy prospects of success. But the men who had cleared the great forest were not to be daunted even by such a disaster. They fought gamely on in spite of the odds and soon the prosperity of the country rose again, Phoenix like from the ashes.' (T. J. Coverdale, loc. cit., p. 359).

## SUBSEQUENT DEVELOPMENT

The rest of the story is an interesting one of the economic weeding out of the unsuitable land. By the 1930s three separate attempts had failed to bring the marginal lands of the eastern Strzeleckis into successful production. Thousands of acres on the steep cold slopes which had been cleared of their valuable mountain ash timber were reverting to scrub, blackberry and bracken. With great skill and enormous trouble the forests are now being partially restored by the Forests Commission and Australian Paper Manufacturers Ltd.

The lower more moderate slopes of the west Strzeleckis and the drained valley bottoms continue in productive animal husbandry, yet an ironic footnote is that in 1969 Australia exported \$76,000,000 worth of dairy produce under cost and imported \$170,000,000 worth of timber!

The future of the region undoubtedly lies in the exploitation of the great fuel resources to the north and south of the Strzeleckis. These developments have already entailed changes in the scale and distribution of settlement and will do so increasingly. Interest has inevitably receded from the Strzelecki axis north to the Latrobe Valley, south to the Bass Strait coasts and to Westernport. Here will be located significant subjects for research in settlement morphology. Perhaps one of the most interesting tasks in historical geog-

raphy is to abstract the factors which seem to control the ebb and flow of man's utilization of the land and for this purpose West Gippsland is a most rewarding study.

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## PROBLEMS AFFECTING THE ECOLOGY OF ISLANDS IN THE WEST GIPPSLAND REGION

By F. I. NORMAN\*

### INTRODUCTION

The islands of Bass Strait and most of the West Gippsland islands lie on the shallow continental shelf joining Tasmania with the Australian mainland. The isolation of the islands is of geologically recent age and Littlejohn and Martin (1965), in a discussion of the affinities of Bass Strait amphibia, considered that the present coastline originated about 6,000 years B.P. Since that time the islands' ecosystems have evolved, only to undergo considerable modification following the advent of European man.

The recent 'Military Survey' map (1:250,000, C.W. Govt. Print., Canberra 1968) of the Victorian coastline names 33 islands and locates a further six. These have an approximate total surface area of 95,000 acres (38,300 hectares). Of these islands 30 (77%) occur along the West Gippsland coast, having a total surface area of about 86,000 acres (i.e. 90% of the total) and a further four are recorded as exposed banks. This paper reviews such ecological data as exist concerning the West Gippsland islands. Where possible, changes known to have occurred on the islands are described and problems peculiar to these islands are noted in a consideration of their importance as conservation units. Whilst the discussion is restricted to the West Gippsland islands, remarks apply also to other Bass Strait islands (included in Tasmanian boundaries S. of 39°12'S.) with which they form an entity.

Fig. 1 shows the location of West Gippsland islands mentioned in the text.

### ISLANDS OF THE WEST GIPPSLAND COAST

#### 1. QUAIL ISLAND 37°14'S. 145°17'E.

A low-lying scrub-covered island about two miles long and one and a half miles wide, Quail

Island lies close to the northwestern edge of Westernport Bay (Ports and Harbours, 1959). The island of c.2,000 acres was declared a sanctuary for native game in March 1928 (and gazetted as a State Game Reserve in 1960). Since then a large population of koalas (*Phascolarctos cinereus*) originating from releases of animals from French Island (165 were released during the 1929-1933 period), has given rise to occasional concern. In November 1943 denuded eucalypts were thought to indicate an over-populated area and the press encouraged the topic (e.g. Melbourne *Herald*, November 6 and December 1, 1943). Subsequently operations by the then Fisheries and Game Department reduced the population and 1,250 of these koalas were released elsewhere in Victoria.

Occasional fires, caused by lightning, or more probably, by man, present to the island a major problem which may increase with the development of the Westernport area.

#### 2. CHINAMANS ISLAND 37°14'S. 145°18'E.

A small mangrove-fringed island occupying about 150 acres; the area was reserved in 1958 for wildlife generally and for koala in particular.

#### 3. FRENCH ISLAND 37°29'S. 145°23'E.

French Island lies across the middle of Westernport Bay, extends eleven miles eastward, and is eight miles wide with the highest point Mount Wellington, 314 ft (95.7m). The island occupies 42,000 acres (16,900 hectares) and has a main ridge two miles wide. This is heavily timbered with manna gum (*Eucalyptus viminalis*) and white gum (*E. rossii*) (Ports and Harbours, 1959). The manna gum was previously more extensive and the stand supported a large population of koalas originating from releases around the turn of the century (McNally, 1957). Between 1928 and

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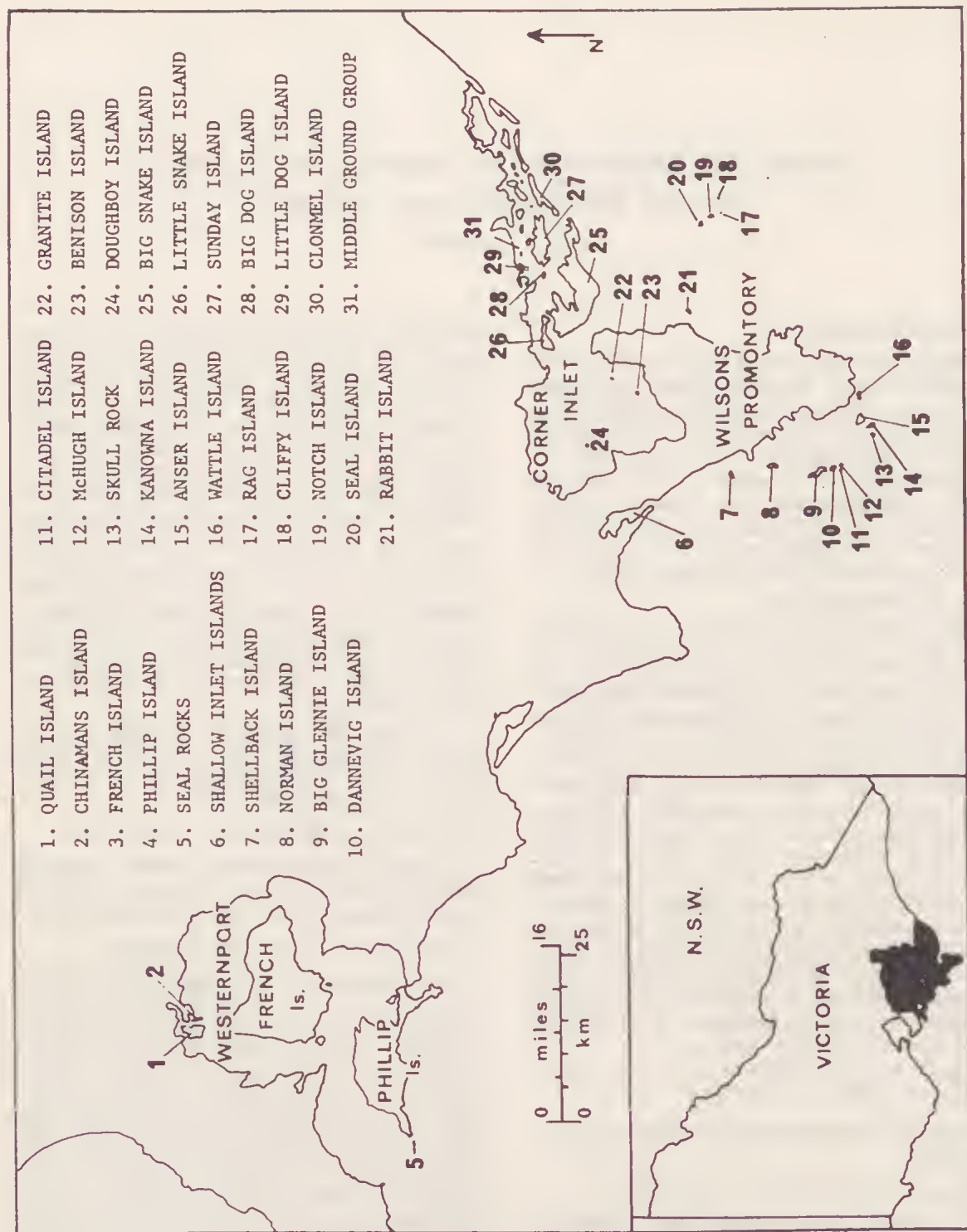


Fig. 1—Islands of the West Gippsland Region.

1940 some of these koalas were taken to Phillip Island. McNally (1957) considered that the vegetation was typical of other similar coastal islands: a comparatively open eastern end with a central and western area covered with scrub and eucalypts including *E. ovata*, *obliqua*, *botroides* and *viminialis*. Along the coast tea-tree is thick, and presumably as a result of clearing fires, bracken (*Pteridium esculentum*) is extensive. In 1954 McNally estimated that the koala population was about 800 to 1,000 but he noted that reduction of timber was being carried out. Such decrease in food supply would lead to an over concentration of koalas which would reduce the remaining food and consequently cause a population decline. Land clearance is continuing and now some 20,000 acres (c.50% of the total area) are used for primary production (J. Seebeck, pers. comm.).

Little is known about the island's flora and fauna but potoroos (*Potorous tridactylus*) and the native rats (*Rattus fuscipes* and *R. lutreolus*) have all been recorded for the Mount Wellington Reserve (131 acres) as have the feral cat, rabbit and house mouse and sambur deer (*Cervus unicolor*) (J. Seebeck, pers. comm.) It is notable that the island apparently lacks echidnas (*Tachyglossus aculeatus*), possums, bandicoots *Antechinus* and *Sminthopsis* spp., wallabies and platypus (*Ornithorhynchus anatinus*) even though these have all been recorded around the perimeter of Westernport Bay.

Clump Lagoon Water Reserve (54 acres) provides some habitat for waterfowl as do various swamps along the northern edge (particularly Decoy and Bullock Swamps) and the extensive mud flats and shoals along the western and northern shores. The short-tailed shearwater (*Puffinus tenuirostris*) has recently been recorded as breeding on the Tortoise Head region (R. West, pers. comm.).

French Island habitats have suffered, and will continue so to do, from the increasing land alienation. It seems likely that fires in the past contributed to wildlife destruction and as commercial facilities expand in the Westernport area, clearing will accelerate, with a consequent reduction of flora and fauna.

#### 4. PHILLIP ISLAND 38°15'S. 145°15'E.

Phillip Island, of 24,320 acres (c.10,000 hectares), lies to the south of French Island across the Bass Strait side of Westernport Bay. The island is separated from the Victorian mainland by the Western and Eastern Passages, about five miles, and one quarter of a mile wide, respectively. The crescent-shaped island is approximately 12 miles long and almost five miles wide. The land

is generally low, undulating and its highest point, 358 ft (109.2m), is on Cape Woolamai within the Fisheries and Wildlife Reserve. Patton (in Gliddon, 1963) considered that the island had probably not been heavily timbered originally, but was open grassland interspersed with manna, blue and swamp gums, and with fairly plentiful stands of wattle. Large saltmarshes occur, particularly along the northern edge, and these become isolated mangrove swamps in places. Freshwater swamps of tea-tree and reeds are common.

D'Urville, commander of the *Astrolabe*, recorded sealers along the western coast in 1826 (Warneke, 1968), and Haydon (1846) confirmed that settlement of part of the island had begun prior to 1842 when the McHaffie brothers began leasing the island (Gliddon, 1963). Later in 1869 and 1870, the island was opened for selection (Melbourne *Argus* November 3, 1869) and parish plans show that 53.3% of the total island area was sold between 1869 and 1889 (Norman and Gottsch, 1969).

Norman and Gottsch (loc. cit.), in reviewing the status of the colonies of *P. tenuirostris* (locally known as the mutton bird), gave a short account of man's activities on the island. Europeans were responsible for extensive clearing, the introduction of stock and the release of alien mammals. Rabbits were introduced about 1860, fallow (?) deer 1867, and the fox about 1908 (Gliddon, 1963). Much of this activity affected the island's wildlife.

The total breeding area occupied by muttonbirds was estimated at 620 acres by Sutton (1933) but in 1967, Norman and Gottsch (loc. cit.) reported that the area had decreased to 310 acres, with several factors aiding in the reduction. Not only did grazing and trampling by stock, and frequent burning of vegetation assist in the formation of mobile sand drifts which swamped colonies (Campbell, 1928) but the widespread practice of 'birding' (taking of eggs, adults and young) reduced numbers (Campbell and Campbell, 1913). Legislation was introduced to remove destructive factors. All birding was prohibited, 1924, and reserves were established at Forrest Caves, Swan Lake, and more recently on Cape Woolamai. Today stock, mobile sand and extensive birding are of no importance though foxes take a small percentage of muttonbirds. However it is readily apparent that the major threat to the muttonbirds and to wildlife generally is the increasing real estate development with concomitant increases in human disturbance and the occurrence of fires.

Fires present a major problem to the reducing stands of *Eucalyptus viminalis* and the koalas which they support. Reserves set aside for wildlife



on the island include Cape Woolamai (320 acres), water reserves (c.500 acres), and 623 acres primarily for the protection of koalas. Waterfowl habitat is reserved in the 330 acres of Rhyll Swamp where ibises (*Threskiornis molucca* and *T. spinicollis*), teal (*Anas gibberifrons* and *A. castanea*) and other duck breed. The attraction for tourists of penguins (*Eudyptula minor*) has been recognized in the provision of 10 acres of reserve at Summerland Beach.

#### 5. SEAL ROCKS 38°02'S. 145°06'E.

Two small basaltic rocks (seven acres) lying off the south-western corner of Phillip Island make up Seal Rocks, which support an extensive population of the fur seal (*Arctocephalus doriferus*). Lee (1915) recorded sealers working the area in 1801, and in 1813 some 922 seals were killed there in a few days (Warncke, 1968). The seal population had been reduced to c.100 by 1860 (Warneke, loc. cit.) and the Rocks were declared a sanctuary in 1882: the species became protected in 1890. In 1947 this protection was lifted with an open season, and about 700 seals were killed, since they were thought to be competing with commercial fishermen for fish and also damaging nets. At present an extensive research programme on the biology of the seals is being conducted by members of the Fisheries and Wildlife Department (Warneke, 1966, 1968).

#### 6. SHALLOW INLET ISLANDS 37°50'S. 146°10'E.

Two small, tussock-covered islands are found within Shallow Inlet: St. Margaret's Island, long, low and crescent-shaped, and McCrae Islet (Ports and Harbours, 1959). These areas are used by Cape Barren geese (*Cereopsis novae-hollandiae*) and numerous seabirds, as roosting areas.

#### 7. SHELLBACK ISLAND 38°58'S. 146°12'E.

The first of the fifteen islands off Wilsons Promontory. These islands have edaphic similarities, with a bedrock of grey, porphyritic granite and derived soils of a coarse-grained sand with varying amounts of organic material incorporated (Gillham, 1961).

Shellback Island rises to 357 ft (108.8 m) and was reputedly well-known for its abundance of Cape Barren geese (Ports and Harbours, 1959) though Dorward (1967) recorded only five pairs on the 80 acre island. Hope (1969) stated that the island flora was dominated by tussock and that no native mammals had been observed.

(According to Ports and Harbours, 1959 it was this island, and not the Glennies, from which Bass ferried marooned convicts to the Promontory mainland).

#### 8. NORMAN ISLAND 39°02'S. 146°12'E.

Norman Island lies about two miles off Wilsons Promontory, rises to 315 ft (96 m) and is some three-quarters of a mile in length. Dorward (1967) considered that the 100 acre island carried approximately five pairs of Cape Barren geese. Hope (1969) records no native mammals from the island.

#### 9. BIG (GREAT) GLENNIE ISLAND 39°06'S. 146°14'E.

The largest of the four islands in the Glennie Group, Great Glennie is about four miles to the west of Wilsons Promontory. It is saddle-shaped, approximately two miles long, and rises to a peak of 455 ft (138.7 m) towards the southern tip (Ports and Harbours, 1959). The four islands of the Group were declared a sanctuary in 1910, and together with Norman and Shellback Islands, became part of the Wilsons Promontory National Park in 1916.

Norman (1967) recorded extensive *Poa* tussock on the northern end of Great Glennie, and to the south, an extensive *Casuarina* forest which also included a variety of smaller scrub species such as *Acacia*. *Poa* tussock is present between the *Casuarina* and in open exposed areas, where perhaps, because of wind and salt spray, scrub species have not invaded after fires. The island supports numerous Cape Barren geese, some of which breed in the tussock (Dorward and Pizzey, 1965). Dorward and Pizzey (loc. cit.) observed 23 birds together with an additional nine pairs, and concluded that during the April-December period, the island was an important breeding ground. Dorward (1967) later thought that the island's 300 acres supported approximately 30 breeding pairs but noted that the island was an anchorage for fishing boats so that predation may have reduced breeding productivity. Earlier Dorward and Pizzey (1965) had recorded the shooting of geese and the removal of young.

The island carries also very extensive colonies of muttonbirds and penguins, has a resident population of olive whistlers (*Pachycephala olivacea*) and the sea eagle (*Haliaeetus leucogaster*) breeds there. Other passerines occur during migratory periods.

Hope (1969) recorded the Marsupial Mouse (*Antechinus minimus*) and *Rattus fuscipes* from the island, the latter (Norman, unpublished data) occasionally reaching high populations.

Here, as on other Promontory islands, fishermen are known to take Cape Barren geese, to collect muttonbirds and to remove penguins for use as cray-pot bait. Enforcement of the various protection laws in this area seems difficult, since

even casual fishermen nowadays have fast boats and can move quickly, but Dorward and Pizzey (1964) suggested aerial and or sea-going patrols which could operate on a non-regular basis and act in conjunction with the local enforcement.

#### 10. DANNEVIG ISLAND 39°06'S. 146°14'E.

Dannevig Island lies close to and south of Great Glennie, is about one half a mile long and 900 ft wide, and reaches a height of 251 ft (76.5 m) (Ports and Harbours, 1959). The area is approximately 80 acres, but the west coast is bare granite and almost devoid of vegetation except for an occasional *Salicornia australis*. *Poa poiformis* tussocks and patches of *Correa alba* are present on the eastern slopes (Gillham, 1961).

Gillham (loc. cit.) found some 2,000-3,000 muttonbird burrows, several hundred penguin burrows and burrows of the diving petrel (*Pelecanoides urinatrix*) on this island. She considered that grazing by Cape Barren geese was of greater ecological importance than grazing by rabbits. But some years later Dorward (1967) recorded only three pairs of geese.

Hope (1969) stated that no native mammals had been recorded for Dannevig, Citadel or McHugh Islands.

#### 11. CITADEL ISLAND 39°07'S. 146°14'E.

This 70 acre granite island, which rises to a flat summit of 385 ft (117.4m) is now almost devoid of soil except for small amounts of granite shingle and 'organic dust' (Gillham, 1961). Vegetation is lacking on the south and west slopes and only on the eastern side does it form more than five per cent cover. *Senecio lautus* is the most abundant species, and scrub species *Correa alba* and *Leptospermum laevigatum* are occasionally present. But altogether only seven species of flowering plants, and two ferns, have been recorded (Gillham, 1960). Gillham (1961) thought that the rabbits present were responsible for the reduction of vegetation. These were placed on the island when the lighthouse was being established in 1913 (Norman, 1970).

Numerous penguins nest in rock crevices but the lack of soil prohibits nesting by muttonbirds (Gillham, 1961). Whilst Cape Barren geese use the island there is now no breeding, though photographic evidence shows that it once occurred there (Dorward, 1967).

#### 12. McHUGH ISLAND 39°07'S. 146°14'E.

The smallest island in the Glennie Group, McHugh Island, rises to 215 ft (65.2 m) (Ports and Harbours, 1959), and occupies 25-30 acres (Gillham, 1961). Most of the island is covered by *Poa poiformis* tussock while *Correa alba*, *Leptosper-*

*mum laevigatum* and *Olearia phlogopappa* represent the scrub flora in the 18 species recorded for the island. Muttonbirds burrow extensively and nests of penguins and diving petrels have been found (Gillham, loc. cit.). Dorward (1967) recorded only one pair of Cape Barren geese.

#### 13. SKULL (CLEFT) ROCK 39°09'S. 146°18'E.

The large, round, sheer granite monolith known as Skull Rock lies one and one half miles from Anser Island, is 371 ft (113.4 m) high (Ports and Harbours, 1959) and has a few tussocks on the summit (Dorward, 1967).

#### 14. KANOWNA ISLAND 39°10'S. 146°18'E.

The middle island in the Anser Group, Kanowna, is one half mile long and about 600 ft wide and reaches a height of 312 ft (95.1 m) (Ports and Harbours, 1959).

Dorward and Pizzey (1965) recorded three pairs of Cape Barren geese and later Dorward (1967) considered that 15 pairs were present on the 100 acre island. Dorward and Pizzey (1964) recorded and photographed approximately 300 fur seals on the island; of a sample of 53, six were full-grown bulls, 17 cows or half-grown young, and 30 were last season's young.

#### 15. ANSER ISLAND 39°09'S. 146°18'E.

The largest of the three islands making up the Anser Group (named apparently from the numbers of geese inhabiting the area), Anser Island is 498 ft (151.8 m) high, a mile long and about a quarter-mile wide. The island lies almost two miles off the southwestern point of Wilsons Promontory (Ports and Harbours, 1959).

Dorward (1967) recorded approximately 20 pairs of Cape Barren geese on the 200 acre island which Hope (1969) stated had a heathy vegetation. Hope recorded no native mammals for the Anser Group which was included in the Promontory National Park in 1916.

#### 16. WATTLE ISLAND 39°08'S. 146°23'E.

Dorward (1967) recorded three pairs of Cape Barren geese on this 70 acre island.

#### 17. RAG ISLAND 39°09'S. 146°19'E.

This is the first small island in the Seal or Direction Group (named by Stokes, 1846). The Group consists of four islands and three rocks all lying in a northwesterly direction about seven miles to the south east of Rabbit Island.

Rag Island is about one mile from Notch Island; it reaches a height of 94 ft (28.7 m) (Ports and Harbours, 1959), and Dorward (1967) recorded three pairs of Cape Barren geese on the 40 acres.



## 18. CLIFFY ISLAND 38°57'S. 146°42'E.

Cliffy Island, lying 12 miles off Wilsons Promontory, is granite rising to 144 ft (43.9 m) and is approximately 400 yards wide and 300 yards long (Ports and Harbours, 1959). The island has a lighthouse which was established in 1884.

Gillham (1961) recorded 39 plant species from the island but noted that only about three acres around the summit carried any depth of soil: most of the area was barren granite. The alien content of the flora was high (45%) according to Gillham (1960). Hope and Thomson (1971) found major communities of *Disphyma australe* and *Poa poiformis* with minor communities of *Salicornia quinqueflora* and *Senecio lautus*. They recorded a total of 41 vascular species.

Gillham (1961) recorded a small muttonbird population, penguins, and about 100 pairs of the silver gull (*Larus novae-hollandiae*) also breed there. Dorward (1967) did not record Cape Barren geese.

## 19. NOTCH ISLAND 38°57'S. 146°39'E.

Lying one mile off Seal Island, Notch rises to 123 ft (37.5 m) and is about 600 yards long by 400 yards wide (Ports and Harbours, 1959). Dorward (1967) recorded three pairs of Cape Barren geese on the island.

## 20. SEAL ISLAND 38°56'S. 146°37'E.

Rising to 154 ft (49.9 m) Seal Island is about 800 yards long, 400 yards wide; coarse tussock covers most of the surface which is burrowed by muttonbirds and penguins (Ports and Harbours, 1959). Goats were liberated there in 1884 as a food source for the lighthouse attendants from Cliffy Island (Ports and Harbours, 1959).

Dorward (1967), noting that the vicinity is a fishing place, found only four pairs of geese on the 50 acres.

## 21. RABBIT ISLAND 38°55'S. 146°31'E.

Rabbit Island lies about three-quarters of a mile from the east coast of the Promontory and rises to 192 ft (58.5 m), occupying about 80 acres (Ports and Harbours, 1959). Norman (1967) described its physical structure in detail and listed 35 vascular plants recorded from this island to 1965, compared with Gillham's (1961) list of 24. Gillham (1961, 1962) attributed the comparative paucity of the flora to the grazing pressure exerted by rabbits, which was accompanied by drought and bird action. Since Norman's (1967) report a further 11 species have been collected from the island, making a total of 46, which included nine alien species (Norman, 1970).

Rabbits were released on this island in 1836 (Stokes, 1846) and since then a sand blow has developed across the island's central region. In May 1965 *Poa poiformis* tussock dominated the whole island but *Senecio lautus* formed an extensive belt bordering the sand blow. A few *Correa alba* shrubs were present and a small stand of *Acacia longifolia* occupied a region near the summit (Norman 1967). Since then the whole aspect of the island has changed with the presumed elimination of the rabbit population, both by myxomatosis and '1080' poison. Rapid and very extensive regeneration has taken place, particularly of *P. poiformis*, and widespread seeding of *Acacia longifolia* and *Olearia axillaris* has taken place with the complete disappearance of the sand blow. Muttonbird rookeries, once in the sand blow area, have expanded along with the vegetation. It has been suggested that in the absence of rabbits the vegetation will return to a scrub-dominated interior and a coastal belt of *P. poiformis* with perhaps an eventual decrease in muttonbird rookeries (Norman 1970). Apart from the very extensive muttonbird breeding colonies, penguins are fairly widespread, but Cape Barren geese are unknown. Little falcons (*Falco longipennis*) are thought to nest in the cliffs, and the island is frequented by Bass Strait transit migrants (*Zosterops lateralis*, etc.). No native land mammals have been found. The island was included in the Promontory National Park in 1916.

## 22. GRANITE ISLAND 38°48'S. 146°25'E.

Corner Inlet has three granite islands in the western sector, and also two fairly extensive mangrove (*Avicennia marina*) islands, both of which are low-lying mud and silt flats used extensively by waders and other waterfowl.

Reaching 100 ft (30.5 m) in height, Granite Island lies on the northern bank of the Benison Channel in Corner Inlet, and is about 300 ft wide and 500 ft long. The island is generally bare of scrub, but has extensive tussock which supports a small muttonbird colony (Ports and Harbours, 1959).

Gillham (1961) considered that the three and one-half acre island was the least sheltered of the Inlet islands which she examined. *Poa poiformis* dominated the island and one clump of *Acacia longifolia* was found; the 16 plant species recorded included four aliens (Gillham, 1960, 1961). The island is a nesting place for silver gulls and for black-faced cormorants (*Phalacrocorax fuscescens*).

All Corner Inlet islands have been within the bounds of the Wilsons Promontory National Park since 1916.



23. BENISON ISLAND 38°41'S. 146°22'E.

Benison Island is in the southern part of Corner Inlet, occupies about 19 acres and reaches a height of 150 ft (45.7 m) (Ports and Harbours, 1959). The centre, and eastern side of the island are covered by scrub dominated by *Melaleuca ericifolia* with occasional *Banksia integrifolia*; *Acacia melanoxylon* was also amongst the 59 species recorded by Gillham (1961, 1962). Extensive muttonbird colonies are found, mainly on the western side of the island within the *Poa* tussock.

The island is connected with the Promontory mainland by a low sand-bar which is exposed around low water (Ports and Harbour, 1959). This has enabled foxes (*Vulpes vulpes*) to cross onto the island from the Promontory. Predation of the muttonbirds by foxes is quite extensive and has been studied recently by Norman (1969).

Sea eagles (*Haliaeetus leucogaster*) hunt over the island which has a small resident population of olive whistlers. The island is used as a feeding ground by crows, which eat corpses left by foxes and scavenge along the shoreline.

24. DOUGHBOY ISLAND 38°46'S. 146°18'E.

A granite mass, unexposed when compared with other Corner Inlet islands, Doughboy reaches 80 ft (24.4 m) in height, lies on the southern bank of Doughboy Channel and occupies 10 acres (Ports and Harbours, 1959; Gillham, 1961). The island has the distinction of being the only Promontory island with botanical references pre-dating those of Gillham (1968). Kershaw et al. (1913) visited the area and recorded 50 plant species, six (12%) being aliens, and Gillham (1960) listed 70 species, of which 26 (30%) were aliens. Extensive *Melaleuca ericifolia* occurred on the shallower soil, a large *Eucalyptus viminalis* stand was present on the summit, and frequent scrub species occurred throughout the vegetation. This had been considerably modified since the days when a small hut was built (Kershaw et al., loc. cit.).

This island and the others within Corner Inlet, suffer considerably from the activity of illegal muttonbirding, though there have been several convictions for this in recent years. Fires and minor clearing operations, generally initiated by fishermen, give some cause for alarm.

25. BIG SNAKE (LATROBE) ISLAND 38°56'S. 146°33'E.

Big Snake Island, and others on the eastern extremities of Corner Inlet, have recently (1964) been included in an extensive State Wildlife Re-

serve. The Nooramunga Reserve of approximately 24,600 acres is composed of all inlets, islands, banks and shoals along the coast (apart from Sunday Island which is operated under a separate agreement). These islands are all subject to considerable erosion, and changes of shoreline are frequent (Ports and Harbours, 1959).

Big Snake, a low-lying island which forms the coast between Corner Inlet and Port Albert, has a tall-timbered interior, mainly of 'honeysuckle' (*Banksia serrata*) and is well grassed (Ports and Harbours, 1959). Taylor (1969) estimated the island's area as being 11,500 acres.

Taylor (loc. cit.) mentioned the introduction of hog deer (*Axis* (= *Cervinus*) *porcinus*) into the area in 1866, from India or Ceylon. These have apparently little effect on native herbivores and Taylor stressed the importance of this population as the only isolated one outside the native range of the species. At present live stock is allowed on the island on agistment between late autumn and early spring, though numbers are limited to 1,000 head of cattle.

The island has, in the past, had populations of echidnas, swamp wallabies (*Wallabia bicolor*), grey kangaroos (*Macropus major*), and possums, though none of these are now present (P. Taylor, pers. comm.). *Rattus fuscipes* has been recorded, also foxes and a few rabbits. Koalas were introduced in 1945 and 1955 but fires are thought to have reduced their numbers, since few were seen in late 1961. However koalas were released there in 1963.

Fires, perhaps purposely lit, burnt through some 3,000 acres in 1966 and destroyed much of the scrub. Whilst this may have affected the small wallaby population, it appears that light burns of the vegetation are beneficial to both deer and kangaroos. However on such an island total destruction of habitat by fire is not unlikely.

26. LITTLE SNAKE ISLAND 38°47'S. 146°30'E.

Taylor (1969) gave the area of this island as 1,500 acres; it is low-lying, with a mangrove swamp along the western coast (Ports and Harbours, 1959). Occasional deer, kangaroos, and emus (*Dromaius novae-hollandiae*) move into the area from the mainland at low tides, and also cross to other local islands at low water when many islands are joined by mud flats (P. Taylor, pers. comm.). The island was grazed in the past and it was considered that the large grey kangaroo population competed with stock. Accordingly 400 kangaroos were shot between 1919 and 1934, 250 in 1959, and 347 in 1960. Koalas were released on the island in November 1967 (information from Fisheries and Wildlife files).

## 27. SUNDAY ISLAND 38°42'S. 146°38'E.

Encircled by Snake, Midge and Main North Channels, Sunday Island lies between Big Snake Island and Port Albert. It is about five miles in length, about two miles wide and occupies about 4,000 acres. The whole island is openly timbered with *Banksia serrata* and *E. viminalis*, apart from the Drum or Drum Island (an island only at low water) (Ports and Harbours, 1959; Turner, Carr and Bird, 1962). Drum Island is openly wooded with a stand of manuka (*Leptospermum* sp.) (Ports and Harbours, 1959).

Sunday Island has four distinct land types: dune ridges, sandy terraces, salt swamps and freshwater swamps. The older dune ridges along the centre are almost encircled by swamps and salt marshes. Terraces on landward sides of ridges are presumed to be old sand flats (Turner et al., 1962) and the vegetation shows five zones indicating five stages of succession.

This island has been used as a grazing run from about 1860 and a homestead was occupied between 1918 and 1938. Cattle were first grazed but later (presumably after clearing and improvement) up to 2,200 sheep were run (Turner et al., 1962). Goats were introduced in 1928 and were still present in 1947 (and perhaps in 1965, P. Taylor, pers. comm.). Most grazing was apparently in lower regions as Turner et al. (loc. cit.) considered that the sand ridges and hollows appeared to be in an ungrazed state, and recorded 254 vascular species, including 32 (12.7%) aliens. Occasional fires have not seriously damaged stands of trees but have encouraged *Pteridium esculentum* in places. Wallabies and rabbits were once numerous but myxomatosis reduced the rabbits and the wallabies were all killed off by wild dogs by 1950. However occasional grey kangaroos, wallabies and foxes still arrive on the island and *Antechinus (swainsonii)* ? and pygmy possum (*Cercartetus nanus*) have recently been recorded (P. Taylor, pers. comm.).

Sunday Island is now being run as a hog deer management area and is probably the first co-operative project in Australia where attempts at increasing a game species are being made by a private organization. The scheme was further discussed by Cowling (1969), Manning (1969) and Taylor (1969).

## 28. BIG DOG ISLAND 38°41'S. 146°15'E.

A low-lying island (about five ft high) covered by grass and light timber, which extends about one and a half miles and is three-quarters of a mile wide. The mangrove-fringed island is a cattle run (Ports and Harbours, 1959) on which goats, rabbits and foxes occur (P. Taylor, pers. comm.).

## 29. LITTLE DOG ISLAND 38°41'S. 146°15'E.

A small island approximately one mile by one quarter of a mile, used as a cattle run (Ports and Harbours, 1959).

## 30. CLONMEL ISLAND 38°44'S. 146°35'E.

Clonmel Island lies at the southwestern end of the Ninety-Mile Beach and is described in detail by Turner et al. (1962). The island's embryonic dune system is backed by high foredunes, and transition to dune scrub occurs. In the latter area *Acacia longifolia*, *Olearia axillaris* and *Helichrysum gunnii* are dominant, attaining heights of up to 25 ft.

## 31. MIDDLE GROUND GROUP 38°43'S. 146°16'E.

This listing of islands along the West Gippsland coast is terminated with mention of four islets making up the Middle Ground Group. All are small, less than half a mile long and a quarter of a mile wide, and all are low-lying. Bullock Horn Islet is samphire-covered (? *Disphyma*). Inner and North Mangrove Islets are mangrove-dominated and Mary Islet has both mangrove and scrub (Ports and Harbours, 1959).

There are several other small areas of mangrove-covered mud bank in this region of Corner Inlet. All are submerged at high tides and all are subject to frequent, severe erosion.

## DISCUSSION

This review of the islands of the West Gippsland coast has shown that there is a lack of information concerning almost all aspects of their ecology. On the islands for which information is available, modification of habitat has taken place and is still continuing. These facts become more pertinent when it is realised that the island habitats are not represented elsewhere. Their uniqueness allows measurement of short-term evolutionary processes in established plant communities and in successful animal populations. Further, if the disturbed habitats, modification patterns have been different from one island to the next, and the interaction of man with this particular environment may be measured against varying historical backgrounds. The interactions of the introduced mammals, native flora and native fauna may also be studied in isolation, and in areas where variations in complexity occurred or still occur.

In this region as elsewhere man has been the main factor causing ecological distress. Man has influenced island faunas directly both by becoming an alien predator and by destroying or severely modifying habitats by clearing and firing vegeta-



tion, and by deliberate introduction of alien herbivores. Stock has been held responsible for vegetational modification by selective grazing or by trampling, and perhaps also for soil modification (Bharucha and Shankaranarayan, 1958). Stock may also destroy burrows of ground-nesting species such as the muttonbird (Mattingley, 1938) or even cause soil consolidation to the extent that burrowing becomes impossible (Littler, 1910). Thus sheep grazing has been held responsible for local reductions in muttonbird numbers (Campbell, 1900; Serventy, 1958), though Norman (1969) concluded that sheep were not contributing to failure of breeding seasons, nor were they preventing expansion of existing nesting areas.

Predation of the Cape Barren goose is still prevalent in Bass Strait waters and on islands in the West Gippsland region (Dorward, 1967). Dorward and Pizzey (1965) mentioned the removal of young geese (to be eaten later, when larger grown) from the Glennie Group which, with other islands off the Promontory, make up breeding habitat for 5% of the world's Cape Barren goose population (Dorward, 1967). Man also removes a part of the annual production of muttonbirds bred on Corner Inlet and Promontory islands and from the Phillip Island colonies. Penguins are similarly taken, though not as food but as bait for crayfish pots. The fur seal which breeds at four sites in Victoria, including Seal Rocks, is protected, but nonetheless the species is still persecuted.

Clearing of vegetation, by fire or by other means, is a seemingly more indirect but more positive method of ensuring that habitats, and

thus the faunas which they support, are reduced. The severity of such habitat removal can determine whether a population becomes extinct or merely reduced to a locally insignificant level. Norman and Gottsch (1969) showed that whilst muttonbird colonies on Phillip Island had contracted by fifty per cent during the past 40 years, clearing was still taking place. Fires on these Phillip Island breeding areas have caused destruction to both breeding adults and to their young in the past few breeding seasons. In the same area clearing fires have reduced food sources for the koala and have occasionally destroyed the koalas themselves. Elsewhere on Phillip Island clearing of wildlife habitat continues apace with the eventual spread of real estate development. Scrub removal and associated land improvement of grassland has resulted in many areas being rendered useless as faunal habitat and in the reduction of entire plant communities. Improvement of grazing areas often involves a reduction of native herbivores which may be competing for food in an environment increasingly unfavourable to them (see also Marlow, 1958).

Alien plant species have often been associated with land clearance and with the introduction of stock. Table 1 shows the extent of alien content on those islands which have been studied, and the table also allows comparison with the species recorded for Rodondo Island (seven miles to the south of the Promontory) which has not received any apparent disturbance from man (Bechervaise, 1947; Willis 1947). Within disturbed island habitats, aliens may be more favoured than native plant species (Gillham, 1960).

TABLE 1  
Disturbance of habitat on selected West Gippsland islands.  
Alien plant species are recorded as a percentage of all plants recorded;  
known human activity, the past or present occurrence of stock and other  
alien mammals is noted (see text for references).

Island	Plants Recorded			Human Activity			Alien Mammals		
	Total	Number Alien	Percent Alien	Clearing	Fires	Stock*	Rabbit	Fox	Others*
Quail				?	+	(+)	+	(+)	
French				+	+	c, s	+	?	d, fc, m
Phillip				+	+	c, g, h, s	+	+	fc, d, m, r
Citadel	7	nil	nil				+		
Dannevig	20	5	25						
Cliffy	41	19	45						
Rabbit	46	9	19.5	?	+		+		
Benison	59	10	17	?	?			+	
Doughboy	78	19	24	?	?		(+)		
Big Snake				+	+	c	?	+	d
Sunday	254	32	12.6	+	+	c, s	+	+	d, dg, fc, g
Rodondo	40	2	5	nil	nil	nil	nil	nil	nil

\* Abbreviations used are + = present, (+) = in past, ? = doubtful, c = cattle, d = deer, dg = dog, fc = feral cat  
g = goat, h = horses m = house mouse, r = rats, s = sheep.

Rabbits were introduced onto several Bass Strait islands as a food source either (Rabbit Island) for potentially shipwrecked persons or (Citadel Island) for provisions for lighthouse attendants (Norman, 1969). For the latter purpose, goats were also placed on Seal Island (Hope and Thomson, 1971). The effects of these releases have been dramatic. Whereas Citadel had an extensive plant cover in the past and one which supported Cape Barren geese (Dorward, 1967), Gillham (1961) could find only seven vascular species on the almost barren island where geese and muttonbirds no longer bred. On Rabbit Island both clearance and the rabbit are thought to have caused widespread erosion which involved destruction of 16 acres of muttonbird colonies and the depression of all seedling growth, including that of scrub species (Norman, 1970). Doubtless rabbits also played a part in the mobilization of sand dunes which swamped breeding areas of muttonbirds on Phillip Island (Campbell, 1928).

Foxes appeared on Phillip Island in about 1908 (Gliddon, 1963) and were soon recorded as predators of muttonbirds (Gabriel, 1919). Since then fox predation has been recorded at all of the 15 Phillip Island nesting colonies (Norman and Gottsch, 1969); this predation removed approximately 1.6% of marked birds in a study area on Cape Woolamai (Norman and Gottsch, 1967). Learmonth (1965) considered that the fox was preventing breeding on the Victorian mainland and indeed it appears that fox predation is causing a decline in breeding adults on Benison Island (Norman, 1969).

Deer were widely released in Victoria and some appeared on Phillip Island in 1869 (Gliddon, 1963) and on Sunday Island in 1866 (Taylor, 1969). However on neither are they numerous and it is doubtful whether competition with marsupials is important.

It is clear that several factors influence the continuance of the island habitats; all factors concern man and his activities. If the various species of birds, discussed above, are worthy of conservation (and existing laws suggests that they are) then equally worthy of conservation are the habitats in which they occur. Even though the West Gippsland islands have 29,445 acres<sup>1</sup> reserved in some form for flora and fauna protection, the majority of islands are unpoliced. These islands are widespread and in regions which are difficult to patrol. Not only is a larger, more mobile enforcement body required but, more important,

there is an acute need for a change in attitude towards wildlife and wildlife habitats generally. For some species, such as the Cape Barren goose and the muttonbird, and for some habitats, much detailed literature exists. However these islands contain many other components for which data are non-existent. Taylor (1968), in discussing related problems affecting islands off the New Zealand coast, recognised two priorities. Firstly that all islands recognised to be in a primitive (undisturbed) state were to be protected, and secondly, that a control of or an elimination of alien mammals on other unstable, actively degrading islands was to be undertaken. Clearly this is an adequate assessment of the present situation on the West Gippsland islands, and for both priorities immediate research is obligatory.

## SUMMARY

Ecological information concerning the West Gippsland islands is reviewed. It is noted that for few species and for few habitats is information available. Problems affecting the islands' wildlife and habitats are recognised. Such problems include the whole range of man's activities, from land clearance for pastoral or real estate development to the introduction of alien mammals. Attention is drawn to the current reduction of wildlife and wildlife habitat and it is concluded that habitat preservation is as important as species protection. Research towards this goal is advocated.

## ACKNOWLEDGMENTS

Much of the background information presented here was gathered whilst I held a Commonwealth Postgraduate Award at Monash University. I wish gratefully to acknowledge the receipt of grants from the M. A. Ingram Trust and the Frank M. Chapman Memorial Fund which enabled field work to be undertaken, and I wish to thank the late Professor A. J. Marshall and Professor J. W. Warren for facilities provided at Monash. Messrs. J. Seebeck and R. M. Warneke (Fisheries and Wildlife Department) provided unpublished information on some of these islands, as did Mr. P. Taylor (Monash University), and the Secretary of the Victorian Fisheries and Wildlife Department allowed quotations to be made from the Department's files.

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<sup>1</sup> Made up by 2,477 acres of State Faunal Reserves, 1780 acres retained under various reserve categories, some islands (totalling 588 acres) off the Wilsons Promontory National Park, 24,600 acres of the Nooramunga State Faunal Reserve.



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# GEOLOGICAL HISTORY OF THE WEST GIPPSLAND REGION

By J. J. JENKIN\*

**ABSTRACT:** In the known geological history of the West Gippsland Region the first events were the development of a geosyncline in the early Palaeozoic and its contraction in the Silurian and Devonian. A major orogeny occurred in the late Middle Devonian and granites were intruded in the late Upper Devonian. Then followed a long hiatus which extended from the Devonian to at least late in the Jurassic.

During the Lower Cretaceous the Eastern Highlands were uplifted and depositional troughs developed to the south. A period of earth movement and erosion followed and, in the early Tertiary, the deposition of clastic sediments and thin coals. Then followed extensive volcanic activity which was in turn succeeded by the deposition of a major coal measure sequence.

Towards the end of the coal measure phase marine transgression occurred, commencing in the Oligocene and reaching its maximum in the Miocene. Regression of the shoreline followed in the late Miocene and Pliocene, with terrestrial deposition again becoming dominant in the later Pliocene.

It was at this stage that the gross topographic form of the present terrain was determined by earth movements along largely pre-existing structures.

The final modifications producing the topographic detail of today are closely related to fluctuations in sea level and climate during the Pleistocene and Recent. These exerted a marked control on erosion and deposition, both terrestrial and marine. Thus the broad physiographic outlines of West Gippsland are morphotectonic in origin, but have been modified by marine and terrestrial erosional and depositional processes.

## INTRODUCTION

The West Gippsland Region is an area of complex and varied geology, all aspects of which cannot be considered within the limits of a short review. Consequently this contribution has been limited to an attempt to show how certain geological events which have taken place since Cambrian times have influenced the development of the present terrain (Table 1).

Outstanding amongst the earlier workers on the geology of the Region are A. R. C. Selwyn (1855) and R. A. F. Murray (1876) who provided a sound basis, in Western Port and South-west Gippsland respectively, on which later contributions have been built. It may be of interest to note that Selwyn's mapping, carried out under very difficult and arduous conditions, was more accurate in many respects than some of the later work. Errors appeared in maps published in the 1890s and were perpetuated in many later maps, a point which did not become apparent until the area was remapped in the early 1960s.

Space would not allow a complete review of the voluminous literature on West Gippsland, but several outstanding contributions come to mind. These include the work on the brown coals by Herman (1922), Thomas and Baragwanath (1949-50) and Gloe (1960), the petrological studies on the Older Volcanics by Edwards (1938), The account of Hills (1942) of the physiography of the Kooweerup Swamp and, more recently, the detailed work of Douglas (1969) on the Mesozoic floras. The reviews by Singleton of the geology of Victoria (1965, 1967a) and of South Gippsland (1967b) are also of particular interest.

## THE PALAEOZOIC FRAMEWORK

The Palaeozoic, from the Cambrian to the Upper Devonian, was a time of exclusively marine deposition and volcanic activity in West Gippsland culminating in a major orogeny in the late Middle Devonian and extensive granitic intrusions in the Upper Devonian. These various Palaeozoic episodes are here very briefly described.

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### CAMBRIAN VOLCANIC ACTIVITY

During the Cambrian vast quantities of basic lavas, with associated tuffs and agglomerates, were extruded. These have been altered (mainly by serpentinization) to a varying extent and are often referred to as 'greenstones'. Ropy flow surfaces and features resembling pillows have been recorded locally. Lenses of chert and shale containing sponge spicules, as well as minor lenses of dark crystalline limestone, are interbedded with the lavas (Lindner, 1953).

These volcanics are thus partly marine and may be entirely so. Although they occur at one locality only within the Region (Waratah Bay) they are of widespread occurrence in Victoria, principally along major structural axes, for example in the Wellington-Barkly area (Harris and Thomas, 1954). It is suggested that this volcanic activity was associated with the initiation of the geosynclinal conditions which became so strongly established in the Ordovician.

The tuffs and shales of Middle to Upper Cambrian age often found overlying the greenstones elsewhere in Victoria are absent at Waratah Bay.

### ORDOVICIAN GEOSYNCLINAL DEVELOPMENT

During the Ordovician a thick series of alternating graded greywackes and shales was deposited

under geosynclinal and anaerobic conditions (Singleton, 1965, 1967a). However, at Waratah Bay and in the Mornington Peninsula, two exceptions to this general uniformity are found.

At Waratah Bay there occurs the only conspicuously calcareous facies in the Victorian Ordovician, that is, the Digger Island Limestone of early Ordovician age. The lower part of the formation consists of grey crystalline limestone, followed by brown decalcified mudstones, then by shales and muddy limestones. The estimated thickness is about 120 ft (Lindner, 1953). The only fossil found in the crystalline limestone is an indeterminate nautiloid, but the brown mudstones have yielded well-preserved trilobites, and the upper beds an 'orthid' brachiopod fauna (Singleton, 1967b).

In the Mornington Peninsula the Ordovician sequence is somewhat condensed, but appears to be complete from the Laneefieldian La2 zone (La1, if present, is not exposed) to the Upper Ordovician. The sequence is also atypical in that it includes the Kangerong Formation, lying between the La2 and La3 zones of the Lower Ordovician, with a lithology reminiscent of the Silurian siltstones and sandstones and completely devoid of dark graptolitic shale.

The Ordovician zones are arranged concentric-

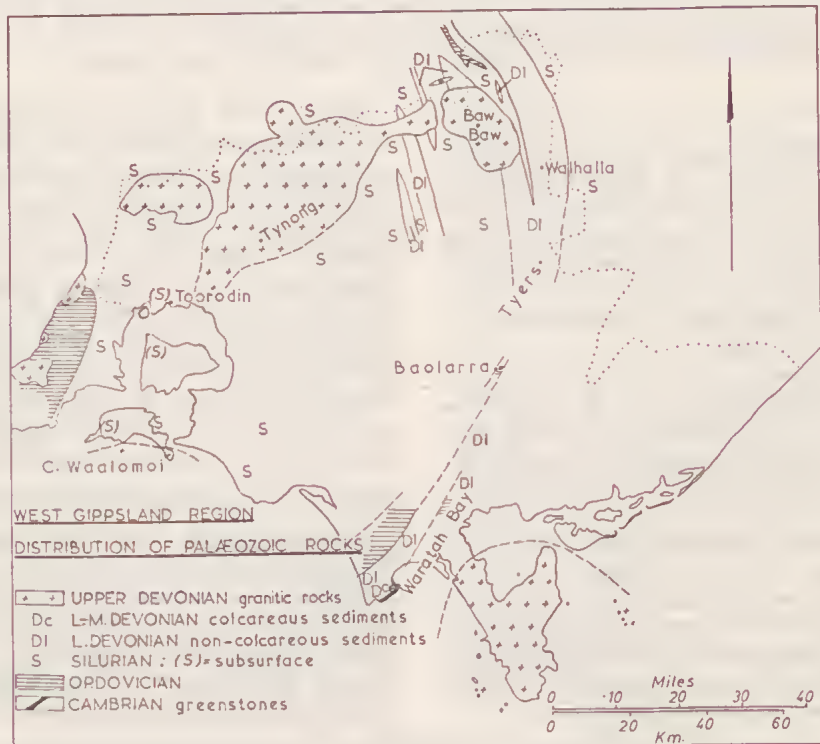


FIG. 1

## WEST GIPPSLAND REGION—GEOLOGICAL EVENTS

	MORNINGTON PENINSULA AND WESTERN PORT	SOUTH GIPPSLAND HIGHLANDS AND WARATAH BAY	CENTRAL HIGHLANDS	GIPPSLAND BASIN
QUATERNARY	Alluvium of present flood plains. Beach ridge, dune and shallow marine deposits		Low-level alluvium	Alluvium of present flood plains. Beach ridge, dune and shallow marine deposits.
Recent				
Pleistocene	High-level alluvium Beach ridge, dune, lagoonal and shallow marine deposits.		High-level alluvium	High-level alluvium. Beach ridge, dune and lagoonal deposits.
	UNCONFORMITY		UNCONFORMITY	
	Warneest Formation Grantville Gravels	Gravels	Haunted Hill Gravels	Haunted Hill Gravels
TERTIARY	UNCONFORMITY		UNCONFORMITY	
Pliocene	Fresh-water clastic sediments, marine silt.	KOSCIUSKO EARTH MOVEMENTS		Boisdale Beds Jemmy's Point Formation LOCAL EARTH MOVEMENTS
Miocene	Baxter Sandstone Sherwood Marl			Gippsland Limestone
Oligocene	Clastic sediments, carbonaceous in part			Lakes Entrance Formation LOCAL UNCONFORMITIES
	LOCAL UNCONFORMITIES			Upper Latrobe Valley Coal Measures
Eocene Paleocene	Basic volcanics and clastic sediments	Thorpdale Volcanics Childers Formation		LOCAL UNCONFORMITIES Lower Latrobe Valley Coal Measures: including Thorpdale Volcanics, Childers Formation.
	UNCONFORMITY		UNCONFORMITY	
CRETACEOUS	Strzelecki Group = Korumburra Group		Tyers Group	Strzelecki Group
Lower	UNCONFORMITY		UNCONFORMITY	
JURASSIC				
TRIASSIC				
PERMIAN				
CARBONIFEROUS			Conglomerates, sandstones, volcanics &c. Granitic rocks	
DEVONIAN				
Upper	Granitic rocks, acid volcanics	Granitic rocks, Wilson's Promontory TABBERABBERAN	ORCENY	
Middle		Bell Point Limestone Liptrop Formation Waratah Limestone	Centennial Beds Deep Creek Limestone	
Lower				
SILURIAN	Sandstones, mudstones and subgreywackes		Sandstones, mudstones and subgreywackes.	
ORDOVICIAN				
Upper	Subgreywackes, shales and slates, frequently cherty	Subgreywackes, shales and slates.		
Middle				
Lower				
Ypsesian Castlemainian Chewtonian Bendigoian Lancefieldian	Incl. Kangerong Formation	Digger Island Limestone		
		UNCONFORMITY		
CAMBRIAN		Altered basic volcanics ("greenstones") with minor sediments.		

TABLE 1

ally around an elongate dome which occupies the west-central part of the Peninsula. The presence of the Kangerong Formation, which is approximately 3,000 ft thick, suggests a shallowing of the sea at this time in the early Ordovician which may be related to an early stage in the establishment of the Mornington structural axis.

Ordovician rocks also outcrop to the west of the Waratah axis, as a small inlier near Boolarra, and as a narrow belt in the axis of the Mt. Easton anticlinorium. However, the area of outcrop of Ordovician rocks within the Region is small (Fig. 1).

## SILURIAN AND DEVONIAN SEDIMENTATION

The close of the Ordovician coincided with a marked change in the nature of the sediments deposited, and in the form of the depositional trough, which became confined between the Mt. Wellington axis on the east and the Heathcote and Mornington axes on the west. At the same time the water became shallower, ripplemark and cross-bedding being quite common, with graded bedding of less frequent occurrence than in the Ordovician sediments.

Lithological changes also appear at the begin-



ning of the Silurian. Subgreywackes are still present in places but siltstones and claystones are dominant while clean sandstones, often fine-grained, are common (Singleton, 1965, 1967a). Bed thickness varies more widely than in the Ordovician rocks and ranges from finely-laminated shale to massive mudstones with individual beds many feet thick. Conglomerates also occur, particularly towards the top of the sequence, as lenses within finer-grained sediments or as persistent bands. In the northern part of the Region occasional lenses of limestone occur within the thick succession of dominantly non-calcareous rocks, for example at Cooper's Creek on the Thomson River.

Deposition persisted throughout the Silurian and Lower Devonian and, despite the change in conditions, followed the Ordovician without an obvious break. The sequence is therefore apparently conformable from at least the early Ordovician to the top of the Lower Devonian.

As Singleton (1967a) points out, neritic shelly faunas, virtually absent from the Ordovician, become progressively more conspicuous through the Silurian and Lower Devonian. Deposition was predominantly neritic although local areas of deeper water, in which dark shales accumulated, occurred from time to time: for example the distinctive *Monograptus-Baragwanathia* shales. In general however, graptolites occur spasmodically in the Siluro-Devonian in contrast to their persistent and widespread presence in the Ordovician.

Two features of the Lower Devonian in the eastern part of the depositional trough are of particular significance. These are firstly, the widespread occurrence of land plants in the clastic, otherwise marine, sediments which suggests the presence of a land area immediately to the east; and secondly, the development of the Waratah and Bell Point Limestones in the Waratah Bay area (Lindner 1953, Teichert 1954, Talent 1965). The occurrence of these calcareous sediments in the vicinity of the Waratah axis suggests the presence of a structural high and probable shoal area. Probably at the same time, mudstones and sandstones of the Liptrap Formation were deposited in the deeper water on the flanks of the axis. This is reminiscent of conditions in this area during the early Ordovician and suggests that intermittent movements occurred along the Waratah axis over a long period.

#### MIDDLE DEVONIAN OROGENY

Deposition ceased in the late Lower to early Middle Devonian, probably due to the onset of a major phase of deformation, known as the Tabberabberan orogeny, which reached its peak in the

late Middle Devonian (Talent, 1965). The strongest effect was produced in the north-east of the Region where all the sediments, including the Lower Devonian, were closely folded. Over the remainder of the area the older rocks tend to be more intensely folded than the younger. This suggests that the older beds may have started to crumple in the subsiding trough while the younger beds were still being deposited, the folding being completed by this phase of intense tectonic activity in the Middle Devonian.

#### DEVONIAN IGNEOUS ACTIVITY

Following the Tabberabberan orogeny, or perhaps during its dying phase, innumerable dykes, known as the Woods Point dyke swarm, were intruded into the folded sediments, particularly along the west limb of the Walhalla synclinalorium (Hills, 1952). The trend of the dykes coincides broadly with the strike of the containing sediments and they have not been affected by the folding although they have been cut by numerous relatively small faults. Auriferous quartz veins often occupy these faults as well as occurring along the walls of the dykes. The dykes range from quartz porphyry to peridotite in composition but diorite and lamprophyre predominate.

Further igneous activity, in the form of large discordant intrusions of granitic rocks, took place in the late Devonian. These include the Baw Baw, Lysterfield, Mt. Eliza and Mt. Martha granodiorites, and the Tynong, Cape Woolamai, Wilsons Promontory and Dromana granites (Fig. 1). Within the Region these rocks have intruded and locally metamorphosed sediments as young as Lower Devonian. In neighbouring areas, for example at the southern end of the Dandenong Ranges, granitic rocks intrude volcanics of Upper Devonian age. They are therefore regarded as being very late or Epi-Devonian in age.

#### MESOZOIC TECTONICS AND SEDIMENTATION

##### THE PRE-CRETACEOUS SURFACE

Although no sediments of Upper Devonian to at least mid-Jurassic age are represented in the Region, an extensive belt of Devonian-Carboniferous sediments and interbedded volcanics occurs about 10 miles to the north-east. Whether or not these rocks once extended into the Region and have since been removed by erosion is unknown.

There is evidence, however, of an extensive pre-Lower Cretaceous erosion surface in south-eastern Australia and it is likely that this surface extended over most, if not all of the Region. It is also possible that this surface started to develop in the later Devonian and continued to form, with

modifications due to epeirogenic movements, faulting and climatic variations, well into Mesozoic times. It may consist therefore of several individual surfaces, but insufficient work has been done to determine whether or not this is so.

### CRETACEOUS TECTONIC ACTIVITY AND SEDIMENTATION

Renewed tectonic activity, which probably started in the Upper Jurassic but reached its peak in the Lower Cretaceous, resulted in a new dominantly E.-W. tectonic trend being superimposed on the general N.-S. trend of the Palaeozoic rocks. This new tectonic style has had a greater over-all effect on the gross morphology of Victoria than any other single event.

These movements produced extensive E.-W. depressions across southern Victoria and were accompanied by broad parallel upwarping to the north which initiated the Eastern Highlands (Hills, 1940). Sediment eroded from the rising land to the north, and possibly also from the south, was deposited in the subsiding troughs. There must also have been some volcanic activity at this time as some of the sediments are tuffaceous, but the source of this material is unknown. As far as the present land area is concerned, there are two of these troughs separated by the ridge of Palaeo-

zoic rocks forming the Mornington Peninsula (Fig. 2).

In Gippsland, a thickness of 9,000 ft of Lower Cretaceous sediments has been proved by drilling, and the total thickness may be much greater. The sediments appear to have been deposited entirely under fresh-water conditions and no major breaks have been detected in the sequence in Gippsland, implying regular subsidence during deposition.

The sediments consist of arkoses, felspathic mudstones and shales, some of which are tuffaceous (Edwards and Baker 1943, Philip 1958, Jenkin 1962). Bituminous coal seams occur in places, as at Wonthaggi (Edwards, Baker and Knight, 1944) and Korumburra, and plant remains are common throughout (Medwell 1954, Douglas 1969). A remarkable fresh-water fish and insect fauna has been found at Koonwarra near Leongatha but, apart from this, animal remains are rare.

Around the margins of the basin, particularly in the Tyers area, at San Remo and on French Island, conglomerates derived from adjacent Palaeozoic rocks occur (Philip 1958, Jenkin 1962). At Rhyll on Phillip Island there is a distinctive coarse arkose (Rhyll Arkose) derived from the Woolamai Granite which lies immediately to the south (Edwards 1945, Jenkin 1962).

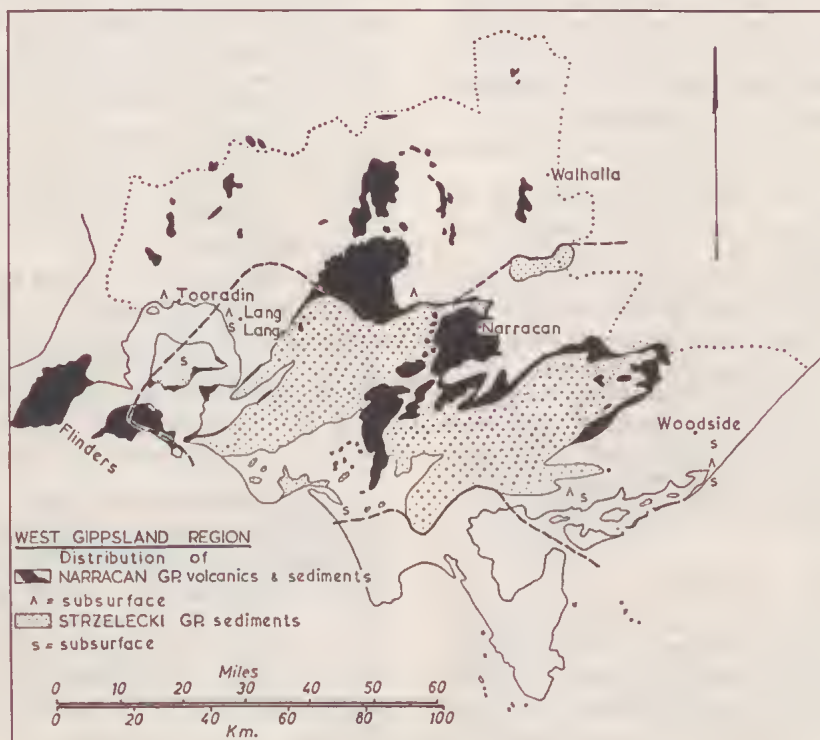


FIG. 2



There is still much uncertainty concerning the conditions under which these sediments were deposited. Lacustrine and flood plain deposition have each been separately postulated (Philip 1958, Singleton 1967b), but both types may be involved. Douglas (1969) has suggested that the initial deposition could have been lacustrine and the occurrence of thick intraformational mudstone conglomerates in the lower part of the sequence supports this contention. However, the presence of rootlet horizons and the xeromorphic nature of much of the flora higher in the sequence indicate that the surface was not continuously water covered.

The Lower Cretaceous rocks contain numerous micro- and macro-floral remains which have been documented principally by Dettman (1963) and Douglas (1969). An age range from perhaps Upper Jurassic to Albian has been suggested, but many uncertainties still remain concerning the accurate dating of the deposits and the environments of the floras.

## CAINOZOIC EVENTS

### EARLY TERTIARY SEDIMENTATION

Upper Cretaceous rocks are absent from Gippsland and the next deposits of which there is any record are early Tertiary, possibly Eocene, in age. They rest, often unconformably, on a surface cut in the Lower Cretaceous sediments as well as on older rocks. Thus, in Upper Cretaceous and very early Tertiary times earth movements occurred which uplifted and tilted the Lower Cretaceous rocks. These events were accompanied by considerable erosion which produced the surface on which the later sediments were deposited.

In the north, now the Eastern Highlands, the country was undulating to hilly and gravels, sands and clays were deposited in the valleys. To the south the topography was more subdued and the sediments tended to form extensive sheets containing swampy depressions in which plant matter, now coal, accumulated—the Childers Formation and its equivalents (Thomas and Baragwanath, 1949-50). There is a tendency for these sediments to be thickest in parts of areas which are now downfaulted, suggesting that some downwarping had already commenced (Jenkin, 1962, 1968).

### EARLY TERTIARY VOLCANICITY

Following the first phase of Tertiary deposition widespread volcanicity occurred, with the eruption of vast quantities of basalt, agglomerate and tuff. Activity was intermittent as sediments are interbedded with the volcanics in many places. Appreciable faulting must also have occurred at this

time, as very thick, but relatively local, volcanic sequences accumulated, for example in the Moie Sunkland, and at Flinders where the volcanics are at least 1,300 ft thick. The Flinders sequence contains extensive red horizons which appear to have been produced by subaerial weathering and may well be soils (red boles). Consequently, it has been suggested that the activity was intermittent and the area periodically subsiding (Jenkin, 1962).

In the higher land to the north (Baragwanath, 1925) and in the northern part of the Mornington Peninsula the flows were largely confined to valleys, but in the adjoining, more subdued country they coalesced to form extensive sheets.

### COAL MEASURE DEPOSITION

Following the extrusion of the volcanics and even in the dying phases, tectonic activity continued. Along prominent lineaments, particularly those defining the edges of major sunklands, the volcanics and associated sediments are often tilted at a high angle. In the sunklands, particularly in the Latrobe Valley and Gelliondale areas, extensive bodies of fresh-water sediments containing very thick brown coals were deposited in favourable situations. The coal measure sediments appear to lie conformably on the older sediments and volcanics within the sunklands, but at the margins they exhibit an unconformable relationship to the older Tertiary rocks. For this reason, combined with the fact that the coal seams thin and split towards the marginal structures (Thomas and Baragwanath, 1949-50), it is undoubted that some movement must have continued during the deposition of the coal measures. In addition, appreciable subsidence would have been necessary to accommodate at least 2,000 ft of sediment which accumulated.

In the Latrobe Valley there are several major seams normally separated by beds of clastic sediments, usually fine-grained. Rarely, these splits are absent giving a total continuous coal thickness of over 600 ft. In Western Port, on the other hand, the coal seams are thin, and clastic sediments, mainly clays and sands, predominate (Fig. 3).

The age of the coal measures is still a subject for controversy but it is likely that they span the Oligocene and extend into the Lower Miocene. In East Gippsland they intertongue with at least the lower part of the marine Tertiary rocks, although Carter (1964) denies this, and in Western Port, a similar intertonguing with early Miocene marine deposits has been demonstrated (Keble, 1954).

The subdivision of the coal measures is shown

in Table I and has been described in some detail by Thomas and Baragwanath (1949-50) and by Gloc (1960).

#### THE MID-TERTIARY MARINE TRANSGRESSION

The marine transgression which appears to be contemporaneous in part with the coal measures, started in the Oligocene with the deposition of the Lakes Entrance Formation and reached its maximum in the Lower to Middle Miocene Gippsland Limestone Formation and its equivalent, the Sherwood Marl, in Western Port. A regressive phase started in the Upper Miocene (Tambo River Formation) and continued into the Lower Pliocene (Jemmy's Point Formation). Since Lower Pliocene times there have been minor advances and retreats of the sea and marine and terrestrial deposits are intertongued in southern and eastern Gippsland.

The limits of the Tertiary marine rocks are shown in Fig. 3. In the West Gippsland Region there is little outcrop of these deposits and most of the information concerning them has come from bore data.

#### THE RETURN TO TERRESTRIAL CONDITIONS

In Western Port and on the Mornington Peninsula, during Upper Miocene times, terrestrial deposition spread over a wide area producing the Baxter Sandstone and its equivalents. This formation consists of ferruginous sands and clays with fine gravels prominently developed near the highland margins of the deposits. It is considered that

the Baxter Sandstone was deposited as a series of coalescing alluvial fans adjacent to the highlands which merged into a broad flood plain in the lower country (Keble 1950, Jenkin 1962, Gostin 1966).

Equivalents of the Baxter Sandstone have not been recognized to the east of the South Gippsland Highlands. Their place is taken by the regressive marine sediments already mentioned, but it is possible that the terrestrial sediments overlying the Tertiary marine deposits in East Gippsland could in places extend back into the Upper Miocene.

In East Gippsland, following the retreat of the Lower Pliocene sea, gravels, sands and clays with occasional thin seams of brown coal were deposited. These deposits, the Boisdale Beds and their equivalents, are best developed to the east of the Region, but also occur in the Alberton area and probably in Western Port. Beds deposited in depressions in the coal surface at Morwell may also be equivalent (Jenkin, 1968).

#### THE KOSCIUSKO UPLIFT

Towards the end of the Pliocene, earth movements were renewed and reached their maximum intensity in late Pliocene to early Pleistocene times. The Eastern Highlands reached their maximum height at this time and, to the south, movement was renewed on structures which had been active earlier in the Tertiary. Erosion was accelerated as a result of the increased elevation of the highlands and may also have been influenced by

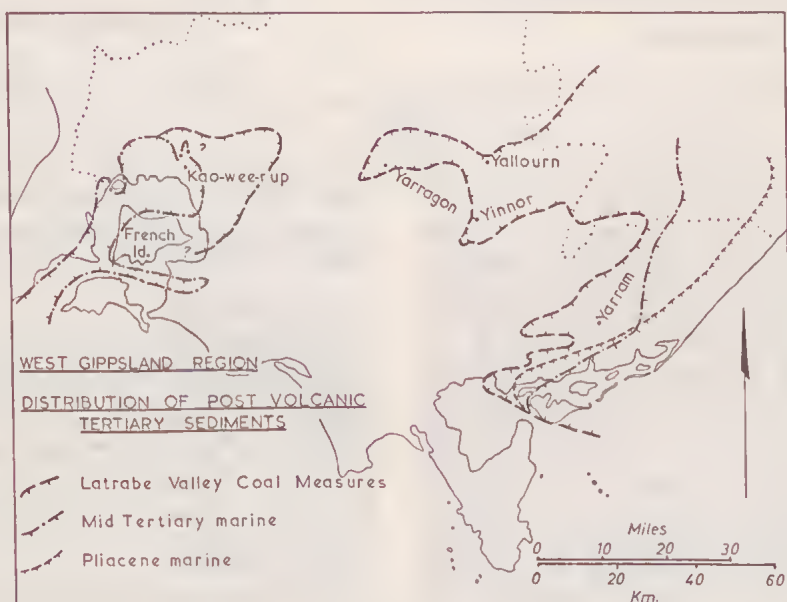


FIG. 3



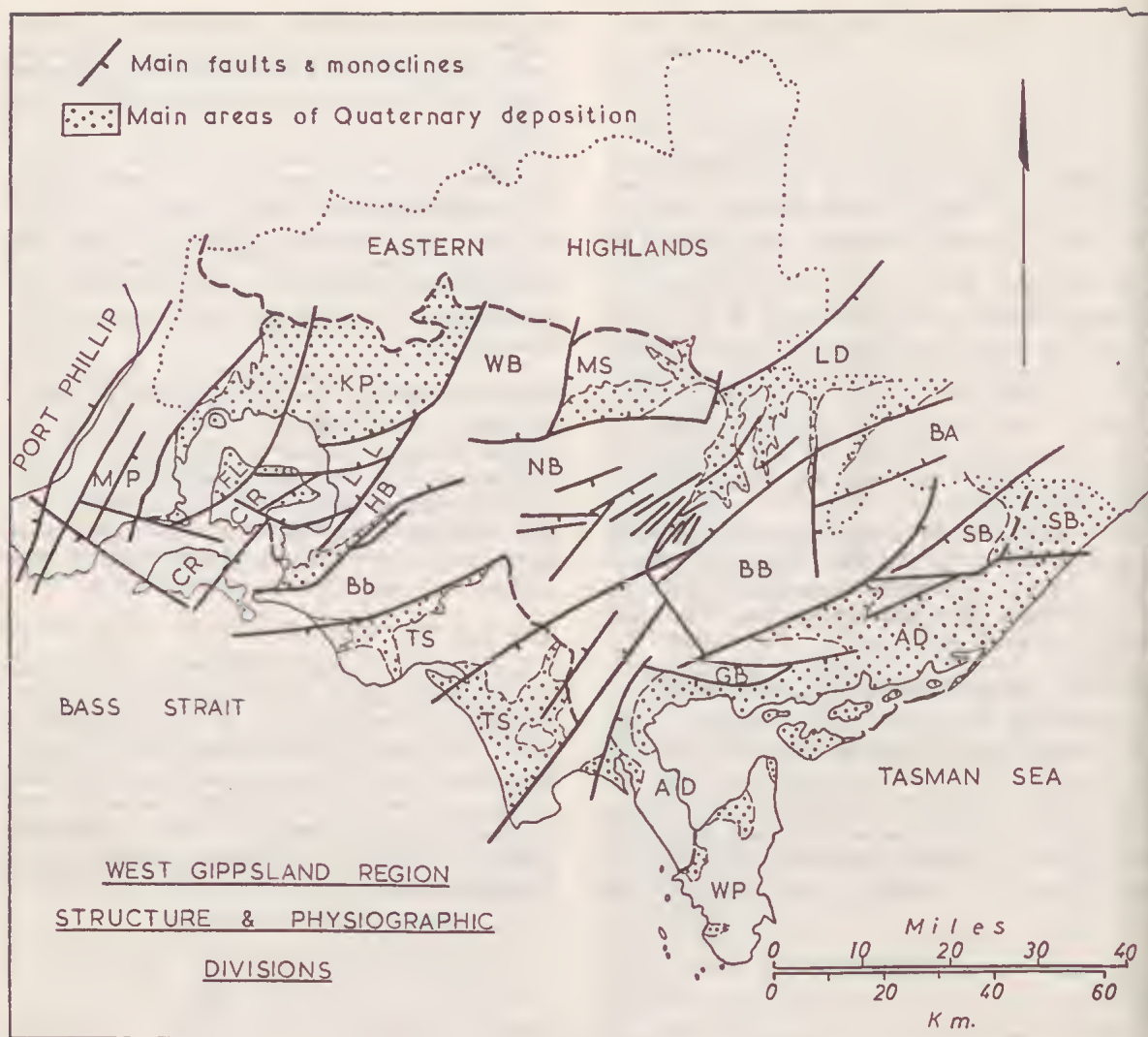


FIG. 4

climatic change. The derived material was deposited as fans and aprons of gravel, sand and clay along, and spreading out from, the structural scarps. These deposits in the central Gippsland area have been called the Haunted Hill Gravels by Thomas and Baragwanath (1949-50) and have extensive equivalents within and south of the South Gippsland Highlands. The Grantville Gravels in Western Port are of similar appearance and approximate age. However, strict contemporaneity of all these deposits is unlikely because of their close relationship to faults and monoclines which were probably moving at different times over the period from mid-Pliocene to early Pleistocene. Earth movements continued into the later stages of deposition, warping the sediments up onto the flanks of the highlands and depressing

them beneath the floors of the sunklands (Hills 1940, Jenkin 1968). Earth movement waned in the earlier part of the Pleistocene although minor activity has continued up to the present time.

#### THE QUATERNARY

The Quaternary era is characterized by oscillating marine, terrestrial and intermediate conditions resulting from eustatic and tectonic movements. The erosional and depositional surface produced in the late Pliocene and early Pleistocene was differentially warped by the continuing, but waning, Koseiuko movements and was partially inundated by the sea which produced sand barriers and bars.

The subsequent regressions and alternating advances of the sea resulted in the formation of

TABLE 2

## WEST GIPPSLAND REGION—PHYSIOGRAPHIC UNITS (cf. Fig. 4)

EASTERN HIGHLANDS	Deeply-dissected plateau reaching 4,500 ft, with higher residuals. Structural and stratigraphic control of erosion pronounced.
SOUTHERN UPLANDS	
(a) Mornington Peninsula (MP)	Dissected ridge of Palaeozoic with flanking Tertiary rocks Reaches 1,000 ft in S. but falls to about 100 ft in N.
(b) South Gippsland Highlands	
(i) <i>Warragul Block</i> (WB)	
(ii) <i>Narracan Block</i> (NB)	Maturely dissected block faulted area of initial low relief. Mainly 500 to 2,500 ft.
(iii) <i>Tarwin Block</i>	
(iv) <i>Balook</i> (BB) and <i>Gelliondale Block</i> (GB)	
(v) <i>Heath Hill</i> (HB) and <i>Bass Block</i> (Bb)	
(vi) <i>Baragwanath Anticline</i> (BA)	Broadly-arched area becoming narrower and lower towards the east (1,000 ft to 100 ft.). Rugged terrain with peaks reaching 2,475 ft.
(vii) <i>Wilsons Promontory</i> (WP)	
WESTERN PORT SUNKLAND	
(a) Kooweerup Plain (KP)	Generally low-lying. Alluvial fan and flood plain deposits; aeolian sands in W., extensive swamps in central area; salt marsh and mangrove fringe.
(b) Lang Lang Lowlands (LL)	Undulating to slightly hilly group of tilt blocks of relatively low elevation.
(c) Bass Plain	Flood plain and delta of the Bass River.
(d) French Island Lowlands (FL)	Predominantly low lying area of sand ridges with intervening swamps and lakes. Salt marsh and mangrove fringe in places.
(e) Central Ridge (CR)	Relatively high group of upthrown blocks with a core of Mesozoic sediments and Tertiary Volcanics.
GIPPSLAND SUNKLANDS	
(a) Latrobe Depression (LD) and Moe Swamp (MS)	Broad alluviated valleys with lateral terraces; extensive swamps.
(b) Stradbroke Block (SB)	Coastal terraces with sand ridges.
(c) Alberton Depression (AD) }	Coastal terraces and sand barriers; alluvial flats and swamps.
(d) Tarwin Sunkland (TS) }	

high-level marine and fluvial terraces with related deposits. The chronology of the high terraces has not been studied in detail within the Region. However, they are of wide occurrence in the Western Port, Tarwin and Woodside areas.

In the country between Corner Inlet and Woodside there is a well-defined series of cliffs, terraces and barriers representing periods of still-stand, each followed by a retreat of the sea. The principal levels are at +45 to 50 ft, +25 ft, +18 ft and +10 ft. The lower of these terraces still shows traces of former tidal channels (Jenkin, 1968).

In the late Quaternary the sea fell well below its present level, which resulted in a marked deepening

of the river valleys. The subsequent rise in sea level, which reached a maximum height of about +10 ft in the mid-Recent, caused infilling of the valleys with estuarine and alluvial deposits and the development of extensive sand barriers on the gently-shelving areas adjacent to or just off-shore. Examples of such barriers are the Corner Inlet islands, and Sandy, Stockyard and Observation Points in Western Port.

Finally, sea level became adjusted to its present position and was accompanied by marine and fluvial activity marked principally by the development of the outer barrier near Corner Inlet, the growth of extensive salt marshes in Corner

Inlet, Western Port and other inlets and alluviation, particularly in the lower reaches of the main streams.

## TECTONIC CONTROL OF THE GROSS MORPHOLOGY

This brief survey of the geological history of West Gippsland shows that the factors influencing the large-scale geomorphic development of the Region are chiefly tectonic and can be traced back to Palaeozoic times, although it is not until the Mesozoic that indications of the present configuration become apparent. The main outlines, however, were clearly defined by early Tertiary earth movements and accentuated by strong movements in the late Pliocene and early Pleistocene.

The physiographic units (Fig. 4) are therefore basically morphotectonic and are bounded, in most cases, by normal faults or monoclines. A brief description of these units is set out in Table 2.

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## SOILS AND LAND USE IN THE WEST GIPPSLAND REGION

By H. P. EDGOOSE\* AND J. B. BARDSLEY\*

The West Gippsland Region, as defined by the Victorian Central Planning Authority (1968), has an area of 5,101 square miles (5.7% of the State). Of this area, 3,153 square miles are occupied, and in 1966-67 there were 9,336 rural holdings with an on-farm population of 37,430. (C. W. Bur. Census Statists., 1969.)

### TOPOGRAPHY

In the north, the Baw Baw plateau rises to over 5,000 ft, and in the south the Strzelecki Ranges to 2,000 ft. Between these two mountainous areas lies the Latrobe Valley, through which the Moe, the Tanjil and the Latrobe Rivers run from W. to E. At the western end of the Region, between Dandenong and Loch, is the large drained Koo-weerup Swamp. Another large area of flat to undulating country is bounded by a line joining Wonthaggi, Leongatha, Fish Creek and Yanakie. To the east of Foster, a narrow coastal plain often less than a mile wide runs to Gelliondale, broadening out around Yarram and Woodside.

### SOILS

The classification of soils for the purpose of this discussion is based on the paper prepared by J. K. M. Skene for the Central Planning Authority Resources Survey of the West Gippsland Region (1968).

Podzolic soils are most widespread in the Region. Important areas of kraznozem occur on Oligocene basalt, and yellowish-grey friable earths are found in the Strzelecki Ranges. Other soil types include acid swamp soils on the Koo-weerup Swamp and around Trafalgar; sandy podzols on the coastal plains between Yanakie and Inverloch; skeletal soils in the higher mountain regions; and small areas of calcareous dune sands along the coast between Western Port and Wilsons Promontory.

#### (1) PODZOLIC SOILS

Podzolic soils in the Region show great diversity. In general they have a bleached subsur-

face, usually with a sharp contrast in texture between surface soil and subsoil. They are acid throughout the profile.

(a) *Lowland sandy soils*: In the Woodside district, these sandy soils are found on undulating plain and low dune country adjoining the Ninety Mile Beach. They are generally slightly acid, and lime is not usually needed for pasture establishment. The principal soil deficiencies are phosphorus, potassium and copper.

(b) *Lowland soils on clay sediments*: These are highly variable. Near Cranbourne, Lang Lang, Yallourn and on French Island they are deep sands, which are strongly acid and require lime for pasture establishment; in other areas, grey loams and clay loams, less strongly acid, are found. Between Yarram and Foster, and near Yannathan, acid swamp soils are associated with this group. Soil deficiencies are phosphorus and potassium, and in the sandy soils and acid swamp soils, copper. Molybdenum is rarely deficient, and may be present at such a high level that it interferes with copper uptake in some of the acid swamp soils.

(c) *Upland soils on miscellaneous rocks*: The parent material for these upland soils is mainly granite in the north of the Region, with some areas of Silurian sedimentary rock. Mesozoic sediments also provide parent material. Granite has given rise to grey, gritty sandy loams varying from slightly acidic to strongly acidic, and the sedimentary rocks to grey loams and fine sandy loams, again of variable acidity. On the granite-derived soils, phosphorus and potassium are the main deficiencies, whilst copper and, much less commonly, molybdenum, may also be required. On soils derived from sedimentary rocks, phosphorus, potassium and molybdenum are the most common deficiencies.

#### (2) SANDY PODZOLS

These are found on the Tertiary and Quaternary sandy deposits of the coastal plains and low dunes in the Inverloch, Tarwin, Yanakie and

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French Island districts. As a group they are more leached than the sandy podzolic soils. Topsoil is commonly extremely acid, and there is frequently a layer of coffee rock in the horizon. These soils almost universally require lime at sowing, and are deficient in phosphorus, potassium and copper.

### (3) YELLOWISH-GREY FRIABLE EARTHS

The yellowish-grey friable earths are formed on the Mesozoic sediments under conditions of high rainfall. These soils are strongly acid, with extremely acid pockets usually at the ends of spurs. They are very well-structured, do not erode badly even in steep country, and particularly at the western end of the Region, are quite fertile. Phosphorus and molybdenum are the main deficiencies. Potassium may be required where potatoes have been grown or where hay has been cut for many years.

### (4) KRASNOZEMS

The kraznozems are derived from Oligocene basalt, and are deep friable soils, moderately to strongly acid. They are uniformly deficient in phosphorus, and commonly in potassium and molybdenum.

### (5) ACID SWAMP SOILS

Both peaty and non-peaty types of acid swamp soils occur in the Region. The peaty types are strongly acid and well-structured and are found in small areas on the Kooweerup Swamp and at Yanakie. More common are the non-peaty types, which fringe the peaty soils and are present in many of the smaller swamps. They are commonly strongly acid grey clay loams. Phosphorus is the main deficiency, but potassium may also be required. Lime may be needed at establishment.

### (6) CALCAREOUS DUNE SANDS

Small areas of siliceous dune sand with calcium carbonate shell fragments fringe the coast between Wilsons Promontory and Western Port. These soils are low in fertility and deficient in phosphorus, potassium, copper and cobalt.

### (7) SKELETAL SOILS

Skeletal soils occur mainly on Silurian sedimentary rocks north of Walhalla and on the

granite on Wilsons Promontory. They are under forest and are not agriculturally important.

## LAND USE

Of the 3.2 million acres in the Region, 1.3 million lie in the upland areas of the Baw Baw Plateau and part of the Eastern Strzeleckis, and are not used for agricultural production. Of the remaining 1.9 million acres, 1.3 million are sown to pasture and a further 0.3 million carry so-called native pasture. Livestock numbers (C. W. Bur. Census Statists., 1969) are set out in Table 1.

## THE DAIRY INDUSTRY

Dairying is the main agricultural industry in the Region and two-thirds of total holdings in West Gippsland are dairy farms. Approximately 80% of these holdings milk more than 40 cows.

Cattle graze mainly on unirrigated pasture with supplementary feeding of hay or silage in winter and late summer when pasture feed is in short supply: about two-thirds of annual pasture production occurs in the three spring months. Fodder crops are used to supplement feed on some farms, but the area sown to such crops is declining. An increasing area is topdressed with nitrogen to supplement winter and early spring feed from pastures.

West Gippsland now carries 30% of the State's dairy herd. The total number of dairy farms has decreased but average herd size has increased, and 50% of Metropolitan Milk Zone Supplies are produced in the Region. From 1959-60 to 1966-67, milk production increased by more than 50%, and dairy production is found on all soil types.

## THE BEEF INDUSTRY

Beef cattle numbers are climbing rapidly and are now thought to be a little over 200,000. British breeds are the most common, but there is also interest in exotic breeds. Beef is also produced from cull dairy cows, and there is a good deal of interest in half-bred dairy-beef cross animals.

Though beef herds are spread throughout the Region, they are more usual in South Gippsland (i.e. south of the Grand Ridge Road).

TABLE 1  
Livestock Numbers, West Gippsland—5 year averages

Type	1943-7	1948-52	1953-7	1958-62	1964-5 (actual)	1966-7 (actual)
Dairy cattle	355,100	396,400	453,600	489,000	544,000	578,450
Beef cattle	87,000	101,000	108,700	142,700	188,300	225,350
Sheep and lambs	522,100	620,900	769,000	845,900	906,900	1,226,400
Pigs	59,300	38,100	43,500	52,900	72,200	58,050

## THE SHEEP INDUSTRY

Only about 3% of the State's flock is found in West Gippsland, and these are mostly in the south. The main production is in fat lambs, using Southdown or Dorset Horn rams over first cross Merino-Border Leicester ewes. There are a few Merino and Corriedale flocks. Some farmers import weaners from other districts for fattening, and sale in late spring and autumn.

## POTATO GROWING

Potatoes are grown principally in the Thorpdale and Kooweerup districts, and there has been a recent increase in the area sown. Now, approximately 10,000 acres are used for potato growing, mainly with supplementary irrigation. The main varieties grown in order of importance, are Sequoia, Sebago, Kennebec and Exton. In 1968-69, West Gippsland produced 54,000 tons of potatoes, 20% of the State's total production.

## OTHER VEGETABLES

Approximately 7,000 acres mainly in the Kooweerup Swamp area are sown to vegetables each year, and nearly 15% of the State's vegetables are produced in the Region. Green peas, asparagus, sweet corn and onions are the major crops, and there has been a recent expansion of pea growing for frozen pea production. In the Warragul district 725 acres were sown to peas in 1968-69, and 625 acres were sown for the 1969-70 harvest.

## FRUIT AND BERRIES

About 3,000 acres of the area are used to grow fruit and berries, with apples the main crop. Around Gembrook, in the far north-west of the Region, some strawberries are grown.

## PASTURES

Pastures of native grasses are rare. There are one and a half million acres of pasture in the Region, of which about one million are topdressed each year with superphosphate or super plus potash.

Pastures usually consist of perennial rye grass (*Lolium perenne*), white clover (*Trifolium repens*), and subterranean clover (*Trifolium subterraneum*), with other sown species and weeds to a varying extent.

Cocksfoot (*Dactylis glomerata*) is common on the friable hill soils, and red clover (*Trifolium pratense*) and strawberry clover (*Trifolium fragiferum*) are common in new sowings and wetter areas, respectively, *Phalaris tuberosa* is grown to some extent on the Kooweerup Swamp. Lucerne is rarely grown as it seldom does well, probably because of the acid soils and waterlogging.

Volunteer species, which occur to a variable extent, are Yorkshire fog grass (*Holcus lanatus*), crested dog's tail (*Cynosurus cristatus*), hair grass (*Vulpia myuros*), sweet vernal (*Anthoxanthum odoratum*), volunteer clovers, e.g. suckling clover (*Trifolium dubium*), and various lotus species.

Weeds commonly seen in pastures are flatweed (*Hypochaeris radicata*), ribgrass (*Plantago lanceolata*), and daisy (*Bellis perennis*). Others relatively common are bracken (*Pteridium aquilinum*), ragwort (*Senecio jacobaea*), rushes (*Juncus polyanthemus* and others), blackberry (*Rubus fruticosus*), thistles (*Cirsium vulgare*, *Cirsium arvense*, *Cardus pycnocephalus*), capeweed (*Cryptostemma calendula*), wild radish (*Raphanus raphanistrum*), docks and sorrel (*Rumex* spp.).

The area of pasture has increased only slightly in the last 20 years. However, the number of dairy cattle has increased by 60%, of beef cattle by 120%, and sheep by 75%, largely because of pasture improvement. The principal fertilizers used are superphosphate and potash, and pasture responses to molybdenum, copper and lime have been recorded. Table 2 shows the increase in the use of artificial fertilizers.

Of 'other' fertilizers (mainly K), West Gippsland absorbs about 40% of the Victorian total usage for pastures, and 27% of the Victorian net total for all uses.

Aerial topdressing is gaining popularity, mainly

TABLE 2

5-Year Period	Use of Artificial Fertilizers—West Gippsland Region			Total		
	Pastures					
	Area (acres)	Super (cwt)	Other (cwt)	Area (acres)	Super (cwt)	Other (cwt)
1943-47	456,700	588,900	11,100	546,200	721,700	70,000
1948-52	785,200	1,084,200	19,700	862,200	1,241,400	67,500
1953-57	885,100	1,234,500	74,500	983,800	1,399,400	151,100
1958-62	1,001,900	1,339,800	209,300	1,099,500	1,492,100	326,200
Actual						
1964-65	1,132,800	1,607,600	261,600	1,180,100	1,686,000	486,400
1966-67	1,195,023	1,697,285	528,043	1,239,732	1,775,517	679,555

in the steeper areas, and some aerial weed-spraying is conducted, chiefly by the Lands Department, in ragwort control.

### FODDER CONSERVATION

Hay and silage making is almost solely from excess spring pasture (98% of hay produced in the Region was pasture hay in 1965). Less than 2,000 acres of oaten hay were baled in 1966.

About 10% of the pasture area is cut for hay in normal years, amounting to some 350,000 tons at an average rate of nearly 2 tons per acre. Similarly, in normal years about 20,000 acres are cut for silage.

Fodder crops are not grown extensively though there are some useful small areas of oats for winter green feed and hay, and of turnips and maize for summer feed. About 18,000 acres is sown to oats, about 6,000 to maize, and another 6,000 to turnips. As well as conserved fodder most dairy farmers supplement feed, commonly with crushed oats, brewers' grains or proprietary feed lines.

### CONCLUSION

The most significant feature of agricultural development in the Region during the last 15 years has been a steady increase in production. Fertilizer programmes matched to soil needs have

given a marked lift in pasture and crop production, and in turn, increased pasture has led to increased stocking rates and higher per acre production. The growing adoption of labour-saving facilities such as herringbone cow-sheds, and also improved farm organization, have enabled increased costs of production to be met by higher productivity.

The actual number of rural holdings is falling. This is partly because of amalgamation of smaller properties and partly because some areas of steep country are being planted to timber. Areas of bush country, mainly to the north of the Princes Highway, have been cleared and sown to pasture. Small areas of vegetables for processing, mainly peas, have been sown under contract for the last two seasons in the west of the Region. More profitable and less wasteful ways of utilizing surplus dairy stock for beef production are being investigated and developed.

In the short term these trends should continue. They demand increasing skill in decision-making for farmers and a changing role for their advisers.

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## FLORA OF WEST GIPPSLAND

By J. H. WILLIS\*

### GENERAL AND SPECIAL FEATURES

The number of vascular plants indigenous to West Gippsland (as defined for the Symposium) is approximately 1,100 species, i.e. about 400 less than the figure for East Gippsland. Such a striking difference cannot be ascribed to any lack of diversity, either in altitude, soil or climate, in this western sector which is actually bounded by a longer, more indented coastline than in the East, and which includes an equally wide range of land forms—from coastal plain to subalpine plateau at 5,000 ft. One obvious reason is the absence of 'jungle pockets' (scattered outliers of subtropical rain-forest that reach into far eastern Victoria from their more continuous development along the coasts of New South Wales). Thus, some 200 species of flowering plants and ferns do not extend west of Bairnsdale. A further group of dryland species, occurring in the rain-shadow belt of the upper Snowy and Deddick River hills, finds no parallel environment in other parts of Gippsland. Another cogent reason for the relative poverty of native plants over much of West Gippsland is the proportionally large area cleared to agriculture and urban development; for instance, the once-extensive heathlands and swamps between Port Phillip and Western Port Bays have now all but disappeared before the demands of housing, industrialization and small farming.

The principal plant communities can be grouped under four physiological categories: Coastal Plains, South Gippsland Highlands, West Gippsland Plains and Main Eastern Highlands (north to the Dividing Range).

1. COASTAL PLAINS: Hereunder are to be included littoral and sand-dune communities, sea-cliff vegetation, salt-marsh and mangrove formations, tea-tree swamps, heaths, some grassland and eucalypt woodland—a very mixed assemblage indeed.

2. SOUTH GIPPSLAND HIGHLANDS (to 2,500 ft, including Wilsons Promontory): These support both dry and wet sclerophyll forests, with ferns

and other shade-loving plants well represented in the shelter of humid valleys.

3. WEST GIPPSLAND PLAINS: Heaths, swamp and riparian communities, and some tussock grassland are present.

4. MAIN EASTERN HIGHLANDS (to 5,000 ft): Very similar vegetation to the South Gippsland Highlands, but including higher montane forest and culminating in a subalpine complex at the Baw Baws where snow lies continuously for weeks during winter and early spring.

Mountain Ash forests of W. and S. Gippsland produced the tallest eucalypts on record—one tree of *Eucalyptus regnans* measured by licensed surveyor at Thorpdale in 1880 was 375 ft and another near Noojee gave a reading of 326 ft in 1888. Such giants have long since vanished.

The great deposits of brown coal in the Latrobe Valley are largely of Oligocene age and are rich in vegetable fossils. These have been the subject of numerous papers by palaeontologist Dr. Isabel C. Cookson (and sundry collaborators) to this Society's *Proceedings*, also to the *Proceedings of the Linnean Society of N.S.W.*, *Australian Journal of Botany* and *Australian Journal of Scientific Research*, during the past two decades.

Most of the 1,100 vascular plants known to inhabit West Gippsland are present also throughout the more southern highland areas or along the coasts of the State, but at least 23 species are restricted in Victoria to this more circumscribed region, nine of these being endemic here and two others almost confined to West Gippsland. The names of the restricted species (with endemics indicated \*) are as follow:

*Lindsaya cuneata* (Wilson's Prom.)

*Adiantum diaphanum* (Lang Lang R.)

*Galinia grandis* (Tomahawk Ck, Beenak)

\**Carex alsophila* (Upper Yarra R. watershed)

\**Astelia australiana* (Bunyip-Latrobe watershed)

\**Thelymitra murdochae* (Wonthaggi-Inverloch region)

\**Microtis holmesii* (Moe district)

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- \**Prasophyllum colemanae* (Bayswater)
- \**Pterostylis crypta* (Waratah Bay)
- Pterostylis fischii* (Woodside & Traralgon districts)
- Australina pusilla* (Wilsons Prom.)
- \**Persoonia arborea* (Yarra, Thomson, Latrobe and Bunyip R. watersheds)
- Grevillea barklyana* (E. tributaries of Bunyip R.)
- Lepidium praetervisum* (Wilsons Prom.)
- Lepidium halmaturinum* (Wilsons Prom.)
- \**Tetratheca stenocarpa* (Yarra, Latrobe & Bunyip R. watersheds)
- \**Acacia howittii* (Tarra Valley)
- Oxalis lactea* (Baw Baw region mainly)
- Pimelea drupacea* (Wilsons Prom.)
- Actinotus bellidioides* (Baw Baw)
- Cyathodes juniperina* (Wilsons Prom. & Phillip Is.)
- Euphrasia gibbsiae* (Baw Baws)
- Coprosma moorei* (Baw Baws & Lake Mtn.)

Some 30 other species of characteristically East Gippsland plants spill over into the coastal tracts of the West, some as far as Wilsons Promontory and a few reaching almost to Port Phillip, e.g. *Dianella caerulea*, *Acacia botrycephala* and *Eucalyptus globoidea*.

Wilsons Promontory and the Baw Baws (both granite) are two areas of particular interest that have been well worked over by botanical collectors. The Promontory has an astonishingly rich flora, embracing at least 665 indigenous vascular species, 90 mosses and hundreds of the higher fungi. Five species of the Promontory's vascular plants are not known to occur anywhere else in the State (although present in Tasmania), viz. *Lindsaya cuneata*, *Australina pusilla*, *Lepidium praetervisum*, *L. halmaturinum* and *Pimelea drupacea*. The endemic daisy-bush, *Olearia alleuderae* is confined to swamps in a few near-coastal heaths of East Gippsland, and to its type locality—along the Vereker Range track on Wilsons Promontory.

Within the subalpine zone (above 4,500 ft) 142 species are to be found on the Baw Baw Plateau, 42 of them confined to springs, bogs and moss-beds. Three Baw Baw species (*Actinotus bellidioides*, *Euphrasia gibbsiae* and blue-fruited *Coprosma moorei*) are isolated outliers from the Tasmanian highlands and do not extend to any other part of Victoria. There is a close floristic affinity between the rather circumscribed Baw Baws and mountains in western Tasmania.

Two plants of outstanding interest are a large tufted lily, *Astelia australiana* which may grow 6 ft tall in sheltered boggy gully-heads, and a unique member of the epacrid family, *Wittsteinia vacciniacea* that trails among mossy boulders and around the butts of old beech trees (*Nothofagus cunninghamii*). Both are endemic in the mountainous watershed of the Yarra, Bunyip and Latrobe Rivers between Mts. Donna Buang and

Erica. The writer discovered this *Astelia* in 1929; it is a spectacular plant, especially when in orange berry about Easter-time, and its closest congeners are 1,100 miles away in New Zealand. The *Wittsteinia*, first collected by Baron von Mueller on the Baw Baws, Christmas 1860, is one of only two genera of vascular plants endemic to Victoria. It is a most intriguing plant, forming a connecting link between the predominantly old-world family *Ericaceae* and the Australasian *Epacridaceae* under which most systematists now place it. The eminent plant geographer, Leon Croizat was so impressed by the isolated taxonomic position of *W. vacciniacea* that he wrote (1952): 'hundreds of other species... have no value to compare with this single one'. In addition to the main strongholds at Donna Buang, Lake Mountain and the Baw Baws, there is a small isolated occurrence of *Wittsteinia* in the King River Valley near Mt. Cobbler.

## BOTANICAL COLLECTORS AND INVESTIGATORS

British botanist George Caley would seem to have been the first collector in the West Gippsland region. Sailing with Lt. James Grant on the *Lady Nelson*, he spent a week in Western Port Bay late in April 1801, but he was not enthusiastic about the flora and gathered few specimens. The Frenchman, M. Leschenault de la Tour, with Captain Emmanuel Hamelin's party on *Le Naturaliste*, arrived a year later. After a brief sojourn at Western Port Bay early in April 1802, Leschenault remarked: 'the number of plants which I gathered here is not great'. Presumably this botanical material is with Leschenault's main collection in the Paris Herbarium.

Sir Paul Edmund de Strzelecki, on his way from Mt. Kosciuszko to Western Port Bay in the autumn of 1840, made natural history collections along the route. Exhausted and almost starving, his party was forced to abandon the horses and all natural history specimens near Boolarra (on the Morwell River) about April 21. They managed to reach Western Port alive 22 days later. After recuperation in Melbourne, Strzelecki left for exploratory work in Tasmania, while his assistant James Riley and resourceful aboriginal guide Charley Tarra are reported to have returned by an easier route to the Morwell River and retrieved the valuable collection of specimens. What happened to them subsequently is not clear.

By far the most important investigator of West Gippsland's vegetation was Baron von Mueller who, between Jan. 1853 and Oct. 1874, made nine exploratory journeys through this area. He

visited both Wilsons Promontory and Mt. Wellington on three separate occasions, and he thoroughly explored the Baw Baws during a fortnight between Dec. 1860 and Jan. 1861. Many of the trophies became types of new species that were subsequently described by Mueller who, in his *Annual Report* to Parliament in January 1861 (pp. 13-15), gives an account of the Baw Baw vegetation.

Mueller's botanical companion on several excursions was Carl Walter who botanized on numerous occasions between 1867 and 1897 around the Dandenongs and Upper Yarra Valley. David Boyle of Nunawading was also active in the Dandenong Ranges between 1867 and 1872, collecting the type material of *Eucalyptus regnans* (Mountain Ash).

Dr. Alfred W. Howitt collected around Sale and Foster in the 1880s, describing the new species *Eucalyptus muellerana* (Yellow Stringybark) from the latter district. Henry Tisdall, a school teacher at Walhalla, gave special attention to the local fungi from 1881 to 1885, and Miss Mary E. Wise of Sale was an assiduous plant collector at the age of 13, in 1895. Rev. James Wilson collected numerous fungi in the Beaconsfield hills (1922-1924) and submitted his material, including several new species to the American mycologist C. G. Lloyd

(Cineinatti). H. T. Clifford's paper 'On the distribution of the species of *Eucalyptus* in the region of the Dandenong Range, Victoria' appeared in *Proc. Roy. Soc. Vict.* Vol 65: 29-55 (1933).

Many subsequent botanical collectors have combed the Baw Baws, and Wilsons Promontory has been rather intensively worked from 1905 to the present day. Ecological studies are currently being made by teams from the University of Melbourne, several of their research papers having already appeared in this Society's *Proceedings*. In Nov. 1969 the Victorian National Parks Authority published a booklet, *The Ferns and Flowering Plants of Wilsons Promontory National Park*, with a complete list of all known indigenous and introduced species. Probably the leading informant on the distribution of higher plants in the Latrobe Valley is Miss Jean Galbraith of Tyers, via Traralgon, who has written several books on Victorian plant-life for the layman. Much research remains to be done on the flora of West Gippsland, and an exciting prospect for those interested in plant mapping is a complete survey of the State, species by species, on grid rectangles of 10 minutes in longitude and latitude. This work, already begun, is sponsored by the Department of Botany at Monash University in association with the National Herbarium.





## THE REPTILES OF WEST GIPPSLAND

By P. A. RAWLINSON\*

### INTRODUCTION

Gippsland is included in Spencer's (1896) Bassian zoogeographic subregion as modified by Serventy and Whittell (1951). Rawlinson (1969) has attempted to show that the reptile fauna of East Gippsland is Bassian in nature and the present account of the reptiles of West Gippsland is intended to complement that of East Gippsland. It should be noted that there is an area of Gippsland (lying between Stratford and 148°E. long.) not covered by these two accounts.

The Bassian subregion lies within the temperate zone and it includes the highest latitudes and altitudes found in Australia. Environmental temperatures decrease with an increase in latitude or altitude; thus temperatures in the Bassian are generally lower than those prevailing elsewhere in Australia. It is possible to recognize three thermal zones within the Bassian, each of which appears to have a characteristic reptile fauna (Rawlinson 1969 and unpublished):

1. *Warm temperate zone*: Coastal plains of E. New South Wales and E. Victoria; inland margins of the Eastern Highlands; the coastal and volcanic plains of SW. Victoria; and the coastal plains and Mt. Lofty Ranges in SE. South Australia.
2. *Cool temperate zone*: Eastern Highlands in New South Wales and Victoria, including the Southern Uplands; the Bass Strait islands; N. and E. Tasmania.
3. *Cold temperate zone*: Alpine areas in SE. New South Wales and E. Victoria; highlands and S. and W. areas of Tasmania; and the islands off S. Tasmania.

West Gippsland, as defined for the 1969 Royal Society of Victoria Symposium, includes the following local government areas (Arnold 1969): the shires of Berwick, Cranbourne, Hastings, Flinders, Bass, Phillip Island, Korumburra, Warragul, Buln Buln, Narracan, Morwell, Mirboo, Woorayl, South Gippsland, Alberton, Traralgon, Rosedale and Maffra, the borough of Wonthaggi;

and the cities of Moe, Yallourn, Traralgon and Sale. The border of West Gippsland as defined by the outermost boundaries of these local government areas is irregular and highly indented. For this reason, an arbitrary border consisting of a series of straight lines running through the towns of Mornington, Dandenong, Warburton, Woods Point, Licola, Stratford and Seaspray, has been used in this account. The area enclosed by this line includes all the local government areas mentioned above. West Gippsland defined in this way includes part of the Eastern Highlands and all the South Gippsland Highlands, and it lies mainly in the cool temperate zone, but the warm temperate zone is represented on the Mornington Peninsula and the West and East Gippsland Plains, and the cold temperate zone is represented on Mounts Baw Baw, Erica, Selma and Useful.

Unlike East Gippsland, there is no single extensive form of vegetation in West Gippsland (Williams 1955, Wood and Williams 1960). The vegetation on the relatively dry West and East Gippsland Plains, S. Mornington Peninsula, French Island and Phillip Island (all of which average less than 30 inches of rain annually) consists mainly of temperate tussock grasslands and temperate tree savannah, both of which are very open. On the N. areas of the Mornington Peninsula, Wilsons Promontory, Yanakie Peninsula, and foothills of the South Gippsland Highlands and Eastern Highlands, average rainfall is higher (more than 30 inches per year) and the vegetation is denser, consisting of mixed coastal woodlands and dry sclerophyll forests. Above 1,000 ft in the South Gippsland Highlands and Eastern Highlands, average annual rainfall exceeds 40 inches and the climax vegetation is wet sclerophyll forest or temperate rainforest, both of which are very dense and prevent solar radiation from penetrating to the ground except where there are clearings, as along rivers and creeks, around swamps and in rocky areas. In the sub-alpine and alpine areas of the Eastern Highlands above 4,000

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ft. the average annual rainfall exceeds 55 inches and is suitable for the development of wet sclerophyll forest and temperate rainforest; however the increasing severity of cold with increasing altitude prevents these vegetation forms from extending above 4,500 ft. Thus climax vegetation varies from dense temperate rainforest and montane wet sclerophyll forest at the lower altitudes, to open sub-alpine woodlands, and to alpine herbfields, bogs, tussock grasslands and feldmarks. Thus the highest altitudes have the lowest environmental temperatures, but the open nature of alpine vegetation allows intense solar radiation to reach the ground in summer. In winter, snow covers the ground for up to 5 months.

Reptiles are restricted in terrestrial environments mainly by temperature as they have no true physiological control of body temperature. They must rely on environmental (external) factors for the maintenance of body temperature and for this reason, reptiles are said to be *ectothermic*. Only birds and mammals have true physiological (internal) control of body temperature, and they are said to be *endothermic*. Although they lack internal control of body temperature, all reptile species have innate (inherited) behaviour patterns which cause them to select the most favourable environmental conditions. During activity, reptiles select conditions which enable them to maintain relatively constant body temperatures, and they can be divided into two groups depending on the method they use:

1. *Heliotherms*: (basking reptiles): use the energy in solar radiation to elevate body temperature; thus they can remain active in low environmental temperatures if they have access to sunshine.
2. *Thigmotherms* (non-basking reptiles): simply select out suitable temperatures in shaded situations; thus they are limited directly by environmental temperatures.

When environmental conditions become unfavourable (either too hot or too cold) reptiles seek out a suitable microenvironment, such as under a rock or a log, and remain inactive until conditions become favourable once more.

## REPTILIAN FAUNA

Twenty-three of the twenty-nine reptile species known to occur in West Gippsland are heliotherms, and they are most abundant in areas where solar radiation can penetrate to the ground such as the temperature tussock grasslands and tree savannah, mixed coastal woodlands, sub-alpine and alpine woodlands, grasslands, bogs and feldmarks, or in clearings in the temperate rainforest and the wet and dry sclerophyll forests. Of

the six thigmothermic species, two (*Denisonia flagellum* and *D. nigrescens*) are nocturnal, and the other four are fossorial litter inhabitants (*Leiopisania delicata* and *L. mustelinum* in forest clearings at low altitudes, *Lerista bougainvilli* under rocks in grasslands and woodlands, and *Anotis maccoyi* in the wet sclerophyll forests at the higher altitudes). As is the case in East Gippsland, only one species (*A. maccoyi*) lives in the wet sclerophyll forests, and the thigmothermic reptile families Gekkonidae, Pygopodidae and Typhlopidae, which are well represented in the warmer parts of Australia, are absent.

Three of the four known SE. Australian reptilian species complexes (Rawlinson 1969 and unpublished) are represented in West Gippsland, the *Sphenomorphus quoyi* and *Notechis scutatus* complexes by one taxon each, and the *Denisonia superba* complex by two taxa. These complexes were discussed in detail under the relevant species headings in the account of the reptile fauna of East Gippsland (Rawlinson 1969).

In the following locality records for West Gippsland, data for each species are presented under four headings:

1. *Specimens examined*: includes the localities of all specimens examined in the collections of the University of Melbourne Zoology Department (MUZD) and the National Museum of Victoria (NMV).
2. *Specimens observed*: includes the author's field records of all reptiles seen but not collected. Road casualties are designated by DOR (dead on road).
3. *Literature Records*: includes all known literature records for West Gippsland.
4. *Distribution*: gives the general distribution of the species based on the author's collecting in SE. Australia and reliable literature records.

Recently published work on the higher taxa of skinks (Fuhn 1967, 1969; Greer 1967; Storr 1964) has enabled a revised taxonomic scheme to be adopted here (c.f. Rawlinson 1969). This scheme is based on Mittleman's (1952) revision of the family Scincidae which splits the Australian species into two sub-families, the Lygosominae and Scincinae. The West Gippsland skink species are listed below under the appropriate sub-families. Mittleman's (op. cit.) work involved a generic revision of the sub-family Lygosominae and his scheme has been adopted here except where there have been recent revisions: following Clarke (1965) the genus *Lampropholis* is not recognized; Fuhn's (1967) genus *Pseudemoia* is adopted as Mittleman (op. cit.) did not list the single species (*P. spenceri*) contained in it; and



the generic changes of Storr (1964), Greer (1967) and Fuhn (1969) are also adopted. These revisions result in the following generic changes from those used in the account of East Gippsland reptiles (Rawlinson 1969):

*Siaphos maccoyi* changes to *Anotis maccoyi*; *Rhodona bougainvilli* changes to *Lerista bougainvilli*; *Emoia spenceri* changes to *Pseudemoia spenceri*.

Although Worrell (1958, 1960, 1961, 1963a, 1963b, 1963c) has published a generic revision of the Australian snakes in the family Elapidae, his changes have gained little support (Rawlinson 1965, 1966, 1967, 1969; Cogger 1967). Recent work by Storr (1967) and McDowell (1969) has failed to support some of Worrell's generic changes, so the older, accepted, generic names used by Kinghorn (1956) are retained here. To standardize spelling and taxonomy of the higher groups (families, sub-orders and orders) the classification of Romer (1956) is used.

# CHELONIA

## CHELYIDAE

### *Chelodina* Fitzinger 1826

#### *Chelodina longieollis* (Shaw 1793)

SPECIMENS EXAMINED: (MUZD) 8 mls. N. of Sale (1); (NMV) Nil.

SPECIMENS OBSERVED: Sale (2).

LITERATURE RECORDS: 12 mls. from Maffra; Rivers of South Gippsland (McCoy 1885).

DISTRIBUTION: Coastally from the Tropic of Capricorn southwards to Sale region, Victoria. Also occurs throughout the Murray-Darling River system, extending from this system into SW. Victoria and SE. South Australia via the Grampians Range.

# SQUAMATA

## LACERTILIA

### AGAMIDAE

#### *Amphibolurus* Wagler 1830

##### *Amphibolurus diemensis* (Gray 1841)

SPECIMENS EXAMINED: (MUZD) Nil. (NMV) Nil. SPECIMENS OBSERVED: Yallourn North (1).

LITERATURE RECORDS: Walhalla (Lucas & Frost 1894).

DISTRIBUTION: Highlands of W., Central and E. Victoria and SE. New South Wales from the Grampians Range (Vic.) to the Blue Mountains (N.S.W.). Also occurs on Flinders Island and in Tasmania.

##### *Amphibolurus murieatus* (Shaw 1790)

SPECIMENS EXAMINED: (MUZD) Shoreham (1); French Island (1). (NMV) Upper Yarra (2).

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Upper Yarra (Lucas & Frost 1894).

DISTRIBUTION: SE. Australia from about the Queensland border southward along the coastal and inland margins of the Eastern Highlands. Also occurs in SE. South Australia.

## *Physignathus* Cuvier 1829

### *Physignathus lesueuri* (Gray 1831)

SPECIMENS EXAMINED: (MUZD) Coopers Ck., 10 mls. S. of Walhalla (1). (NMV) Barkly R., 3½ mls. S. of Gleneairn (1).

SPECIMENS OBSERVED: Glenmaggie Reservoir (5); Thomson R., Walhalla (10).

LITERATURE RECORDS: Aberfeldy (Lucas & Frost 1894).

DISTRIBUTION: E. coast of Australia from the Cape York Peninsula (Qld.) to Walhalla in SE. Victoria. The Gippsland form has been described as a subspecies, *P. lesueuri howitti* (McCoy 1878).

## SCINCIDAE

### LYGOSOMINAE

#### *Anotis* Bavay 1896

##### *Anotis maceoyi* (Lucas & Frost 1894)

SPECIMENS EXAMINED: (MUZD) Oaks Plain, 2 mls. S. of Kel Junction (1); 5 mls. N. of Loch Valley Camp (1); Pennys Saddle, 4½ mls. N. of Loch Valley Camp (2); 4 mls. ENE. of Powelltown (1); 3 mls. E. of Powelltown (1); Kalorama (3); 1½ mls. W. of Kallista (3); 2 mls. S. of Belgrave (4); Dewhurst, 8 mls. N. of Berwick (1); 4 mls. WNW. of Upper Pakenham (2); Upper Beaconsfield (2); 5 mls. SW. of Walhalla (1); 4 mls. SSE. of Walhalla (1); 1½ mls. E. of Warragul (2); Delburn (5); 2 mls. SE. of Darlimurla (1); Shoreham (4); Mt. Oberon, Wilsons Promontory (1); Roaring Meg Ck., Wilsons Promontory (5). (NMV) Kallista (2); Ferntree Gully (8); 6½ mls. SW. of Powelltown (1); 5 mls. SSE. of Powelltown (8); Noojee (2); Neerim North (2); Emerald (13); Cockatoo (2); Walhalla (7); Dandenong (2); Bunyip (3); Brandy Creek (2); Trafalgar (1); Narracan (4); Meeninyan (3); Toora (4); South Gippsland (1); Waterloo, Gippsland (15).

SPECIMENS OBSERVED: Aberfeldy (1).

LITERATURE RECORDS: Walhalla; Millgrove; Mt. Dandenong (Loveridge 1934 as *Siaphos maccoyi*); Brandy Creek; Trafalgar; Waterloo; Ferntree Gully; Fernshaw; Dandenong Ranges; Berwick; Upper Yarra; South Gippsland (Lucas & Frost 1894 as *Siaphos maccoyi*).

DISTRIBUTION: Highlands of SE. New South Wales and E. Gippsland from Bulls Head, Brindabella Ranges (A.C.T.) south, then extending into W. Gippsland and SW. Victoria along the forested coastal plains and southern slopes of the Eastern Highlands.

#### *Leiopisisma* Dumeril & Bibron 1839

##### *Leiopisisma delicata* (DeVis 1888)

SPECIMENS EXAMINED: (MUZD) 2 mls. S. of Belgrave (1); Upper Beaconsfield (5); Heyfield (1); 4½ mls. NNW. of Pakenham (4); 4 mls. N. of Bunyip (1). (NMV) 1½ mls. N. of Boneo (3).

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Nil.

DISTRIBUTION: E. coast of Australia from SE. Queensland southward to just E. of Melbourne, then disjunctly in SW. Victoria, SE. South Australia, Eyre Peninsula, South Australia and in NE. Tasmania.

*Leiolopisma entrecasteauxii* (Dumeril & Bibron 1839)

SPECIMENS EXAMINEO: (MUZD) 10 mls. SE. of Cumberland Junction (1); Oaks Plain, 2 mls. S. of Kel Junction (2); 4 mls. S. of Kel Junction (1); 5 mls. S. of Kel Junction (2); 6 mls. S. of Kel Junction (1); 5 mls. NE. of Loch Valley Camp (4); Mt. Dandenong (1); Mt. Baw Baw summit (25); Smiths Beach, Phillip Island (1); Cape Woolamai, Phillip Island (3); 2½ mls. N. of Darby River, Wilsons Promontory (1). (NMV) Mt. Baw Baw (36); Western Port (1); Meeniyah (1); Wilsons Promontory (1). SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Tynong; Mt. Baw Baw (Lucas & Frost 1894).

DISTRIBUTION: Southward along the Eastern Highlands from Mt. Barrington (N.S.W.), extending onto the coastal plains in S. Victoria and SE. South Australia. Also occurs on Pearson Island, Investigator Group and Kangaroo Island off South Australia; on the Bass Strait islands; and in Tasmania where it is restricted to the N. and E. grasslands and woodlands.

*Leiolopisma guichenoti* (Dumeril & Bibron 1839)

SPECIMENS EXAMINED: (MUZD) Woods Point (1); Millgrove (2); Warburton (1); East Warburton (3); Gilderoy (1); Kallista (1); 2 mls. S. of Belgrave (4); 1½ mls. ESE. of Lysterfield (1); Dewhurst, 8 mls. N. of Berwick (4); Upper Beaconsfield (5); 4½ mls. NNW. of Pakenham (1); Lyndhurst (1); Boola Boola Camp, 3 mls. E. of Moondarra Reservoir (1); 4 mls. N.W. of Tyers (1); 3½ mls. N. of Tyers (2); 3 mls. N. of Tyers (1); 1½ mls. E. of Warragul (2); Delburn (5); 3 mls. SE. of Darlimula (1); Carrajung (1); 9½ mls. WNW. of Yarram (1); Smiths Beach, Phillip Island (2); Bruthen Ck., Woodside (1); Cape Woolamai, Phillip Island (3); 9 mls. E. of Welshpool (1); 8 mls. S. of Fish Creek (1); Shallow Inlet (1); 9 mls. N. of Darby River, Wilsons Promontory (1); 3 mls. N. of Darby River, Wilsons Promontory (2); Tidal River, Wilsons Promontory (1). (NMV) Upper Yarra (1); Monbulk (2); Belgrave (1); Emerald (7); Springvale (1); Cockatoo (1); Walhalla (7); Bunyip (2); Narracan (1); Yarragon (1); Loch (1); Giffard (2); Meeniyah (1); Wilsons Promontory (1).

SPECIMENS OBSERVED: 8½ mls. W. of Stradbroke (10).

LITERATURE RECORDS: Upper Yarra; Loch; Beaconsfield; Ferntree Gully; Carrum (Lucas & Frost 1894).

DISTRIBUTION: SE. Australia generally, from the coast inland to about the 20 inch isohyet. On the E. coast *L. guichenoti* does not extend much further north than Brisbane, and it is absent from the highlands in SE. New South Wales and Victoria. In South Australia, known only from the Mt. Lofty Ranges and Kangaroo Island.

*Leiolopisma metallicum* (O'Shaughnessy 1874)

SPECIMENS EXAMINED: (MUZD) 5 mls. SW. of Kel Junction (1); 2 mls. S. of Kel Junction (1); 4 mls. S. of Kel Junction (1); 6 mls. S. of Kel Junction (4); 11½

mls. S. of Kel Junction (1); 4 mls. NNW. of Mt. Whitelaw (1); Pennys Saddle, 4½ mls. NE. of Loch Valley Camp (1); 3 mls. E. of Pennys Saddle (3); 3½ mls. E. of Pennys Saddle (1); 4½ mls. E. of Pennys Saddle (2); Mt. Baw Baw summit (1); 1 ml. N. of Mt. Erica (1); 4½ mls. NNW. of Pakenham (1); Shoreham (2); Smiths Beach, Phillip Island (7); Cape Woolamai, Phillip Island (3); Waratah, Waratah Bay (1); 2 mls. N. of Walkerville (2); Benison Island, Corner Inlet (4); 2½ mls. N. of Darby River, Wilsons Promontory (9); Darby River, Wilsons Promontory (3); 2 mls. S. of Darby River, Wilsons Promontory (1); Mt. Oberon, Wilsons Promontory (1); 2 mls. SSE. of Tidal River, Wilsons Promontory (1); 5 mls. SSE. of Tidal River, Wilsons Promontory (1). Localities outside West Gippsland: Kalatha Camp (3); Mt. Tanglefoot (3); Toolangi (1); 2 mls. NE. of Mt. St. Leonard (3); Mt. St. Leonard (9); 1½ mls. E. of Mt. St. Leonard (5); Pantons Gap, 7 mls. SE. of Healesville (1); Don Gap, 10 mls. ESE. of Healesville (1); Mud Island, Port Phillip Bay (8); Barwon Heads (1); (NMV) Upper Yarra (1); Mt. Baw Baw (1); 1 ml. from summit of Mt. Baw Baw (1); 6½ mls. SW. of Powelltown (10); 5 mls. SSE. of Powelltown (1); Mulgrave (7); Dandenong (1); Pakenham (4); Bunyip (1); Loch (5); Waterloo, Gippsland (1); Wilsons Promontory (2); Rodonde Island (2); Clifty Island (3).

SPECIMENS OBSERVED: Aberfeldy (1); 3½ mls. SE. of Powelltown (1); 8 mls. NW. of Yarram (1); Roaring Mcg Ck., Wilsons Promontory (1).

LITERATURE RECORDS: Black Rock; Mt. Baw Baw (Clarke 1965); Port Albert (Lucas & Frost 1894).

DISTRIBUTION: Known only from West Gippsland, the E. side of Port Phillip Bay and the Barwon Heads area on the Australian mainland; all known localities are listed above. Also known from most of the Bass Strait islands and on the Tasmanian mainland where it is the commonest species of lizard.

*Leiolopisma mustelinum* (O'Shaughnessy 1874)

SPECIMENS EXAMINED: (MUZD) Dewhurst, 8 mls. N. of Berwick (2); Upper Beaconsfield (1); 1½ mls. NNW. of Officer (1); Delburn (2); Dromana (1); Point Leo (1). (NMV) 2 mls. E. of Longford (2); Trafalgar (1).

SPECIMENS OBSERVED: Jindiviek (1).

LITERATURE RECORDS: Mulgrave; Dandenong Ranges; Upper Yarra; Waterloo; Ferntree Gully (Lucas & Frost 1894).

DISTRIBUTION: SE. coast of Australia from Mt. Barrington (N.S.W.) to just E. of Melbourne, with an isolate in the Otway Ranges (W. Vic.).

*Leiolopisma trilineatum* (Gray 1839)

SPECIMENS EXAMINEO: (MUZD) Upper Beaconsfield (1); Cross Ck., 1 ml. W. of Stratford (1); Shoreham (2); 3 mls. N. of Darby River, Wilsons Promontory (3); 2½ mls. N. of Darby River, Wilsons Promontory (2); Tidal River, Wilsons Promontory (1). (NMV) Bena (1); Wilsons Promontory (1); Cape Schanck (1).



SPECIMENS OBSERVED: 1½ mls. ESE. of Lysterfield (1 DOR).

LITERATURE RECORDS: Brandy Creek; Western Port; Carrum (Lucas & Frost 1894).

DISTRIBUTION: Coastal and inland margins of the Eastern Highlands in SE. Australia from about the Warrumbungle Ranges (N.S.W.) south. Also occurs in SW. Australia, SE. South Australia, Kangaroo Island, the Bass Strait islands and the coastal regions of N. and E. Tasmania.

*Lciolopisma weekcsae*? Kinghorn 1929

SPECIMENS EXAMINED: (MUZD) 4 mls. S. of Kel Junction (1); Kalorama (13); Belgrave (1). (NMV) Mt. Baw Baw (1); 2½ mls. from summit of Mt. Baw Baw (2); 3 mls. from summit of Mt. Baw Baw (1); Waterloo, Gippsland (2).

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Sherbrook Forest; Mt. Donna Buang (Loveridge 1934 as *L. aeneum*?).

DISTRIBUTION: Highlands of SE. New South Wales and Victoria from the Jenolan area, Blue Mountains (N.S.W.) to the Grampians Range (Vic.), with an isolate in the Otway Ranges (W. Vic.).

Lecrista Bell 1883

*Lecrista bougainvillii* (Gray 1839)

SPECIMENS EXAMINED: (MUZD) Locality outside West Gippsland; 1 ml. NNW. of Taberabbera (1). (NMV) Locality outside West Gippsland; Springvale (1).

SPECIMENS OBSERVED: Arthurs Seat, Dromana (2).

LITERATURE RECORDS: Carrum (Lucas & Frost 1894).

DISTRIBUTION: SE. South Australia, Kangaroo Island, Victoria, E. Bass Strait islands and NE. Tasmania.

*Pseudemoia* Fuhn 1967

*Pseudemoia spenceri* (Lucas & Frost 1894)

SPECIMENS EXAMINED: (MUZD) Kalorama (2); 9 mls. NE. of Loch Valley Camp (41); 8 mls. NE. of Loch Valley Camp (1); 7½ mls. NE. of Loch Valley Camp (13); Mt. Baw Baw summit (1). (NMV) Mt. Baw Baw (1); 2½ mls. from summit of Mt. Baw Baw (11); 3 mls. from summit of Mt. Baw Baw (1); Brandy Creek (1); Narracan (1); Meeniyah (1).

SPECIMENS OBSERVED: Tarra Valley (1).

LITERATURE RECORDS: Mt. Baw Baw, 5,000', near summit; Brady (= Brandy) Creek; Dandenong Ranges (Fuhn 1967); Brandy Creek; Dandenong Ranges (Lucas & Frost 1894 as *Emoia spenceri*); Brandy Creek; Dandenong Ranges (Worrell 1963a as *Emoia* (?) *spenceri*).

DISTRIBUTION: Highlands of SE. New South Wales and E. Victoria from the Jenolan area, Blue Mountains (N.S.W.) to Lake Mountain (Vic.), with an isolate in the Otway Ranges (W. Vic.).

*Sphenomorphus* Fitzinger 1843

*Sphenomorphus tympanum* (Lonnberg & Andersson 1913)

*Cool Temperate Form*

SPECIMENS EXAMINED: (MUZD) 4 mls. ENE. of Licola (1); 7 mls. ENE. of Kel Junction (1); 6

mls. ENE. of Kel Junction (1); 1 ml. NE. of Kel Junction (2); 10 mls. SE. of Cumberland Junction (2); Kel Junction (6); 13 mls. SE. of Cumberland Junction (1); 5 mls. WSW. of Kel Junction (1); Oaks Plain, 2 mls. S. of Kel Junction (4); 4 mls. NNW. of Mt. Whitelaw (12); 11 mls. S. of Kel Junction (6); Mt. Whitelaw (4); 9 mls. ENE. of Loch Valley Camp (6); 8 mls. ENE. of Loch Valley Camp (5); 7½ mls. ENE. of Loch Valley Camp (7); 5 mls. NE. of Loch Valley Camp (5); Pennys Saddle, 4½ mls. NE. of Loch Valley Camp (7); 5 mls. NE. of Powelltown (1); Mt. Baw Baw Plateau (3); Mt. Baw Baw summit (7); 2 mls. SW. of Mt. Baw Baw (3); 1 ml. N. of Mt. Erica (1); Kalorama (7); 5½ mls. SSE. of Walhalla (5); 5 mls. S. of Walhalla (1); 7 mls. ESE. of Walhalla (5); 5 mls. W. of Cowwarr (1); 3 mls. NW. of Boola Boola Camp (4); 4 mls. NNW. of Tyers (3); 3½ mls. NNW. of Tyers (2); 3 mls. NNW. of Tyers (4); 2 mls. E. of Buln Buln (1); Merrimans Ck., ½ ml. NE. of Stradbroke (2); Delburn (1); Monkey Ck., 2 mls. SSW. of Stradbroke (1); Causeway Rd., French Island (1); 8½ mls. SSW. of Stradbroke (4); Shoreham (1); 7½ mls. N. of Yarram (1); 8 mls. S. of Fish Creek (2); Shallow Inlet Rd. (1); N. end of Verekers Range, Wilsons Promontory (1); 1 ml. N. of Darby River, Wilsons Promontory (3); Darby River, Wilsons Promontory (7); 2 mls. S. of Darby River, Wilsons Promontory (3); Lilly Pilly Gully, Wilsons Promontory (2); Mt. Oberon, Wilsons Promontory (4); Lighthouse Traek, Wilsons Promontory (1); Roaring Meg Ck., Wilsons Promontory (3). (NMV) Upper Yarra (5); Mt. Baw Baw (5); 1 ml. from summit of Mt. Baw Baw (1); 2½ mls. from summit of Mt. Baw Baw (3); Junction of Tanjil Bren, Erica and Mt. Baw Baw roads (2); Ferntree Gully (1); 6½ mls. SW. of Powelltown (8); 5 mls. SSE. of Powelltown (3); Walhalla (5); Bunyip (2); Korumburra (10); Jumbunna (1); Wilsons Promontory (2).

SPECIMENS OBSERVED: 3½ mls. SSE. of Powelltown (1); Seven Acre Rock, 7 mls. SW. of Powelltown (1). LITERATURE RECORDS: Upper Yarra; Toora (Lucas & Frost 1894 as *Lygosoma* (*Himulia*) *quoyi*); Dandenong Ranges near Melbourne (McCoy 1890 as *Himulia quoyi*).

DISTRIBUTION: *Cool Temperate Form*: Highlands of SE. New South Wales and Victoria from the Jenolan area, Blue Mountains (N.S.W.) southward. Occurs throughout the Victorian coastal plains from Stradbroke (W. Gippsland) to Mt. Richmond (SW. Victoria). *Warm Temperate Form*: Highlands of NE. New South Wales, coastal and inland margins of the Eastern Highlands in SE. New South Wales and NE. and SE. Victoria. Also occurs on the Fleurieu Peninsula, South Australia.

SCINCINAE

*Egernia* Gray 1838

*Egernia luctuosa* (Gray 1832)

SPECIMENS EXAMINED: (MUZD) Locality outside West Gippsland; 10 mls. SSW. of Mallacoota (1). (NMV) Rosedale (3).



SPECIMENS OBSERVED: 1½ mls. N. of Boneo (1).

LITERATURE RECORDS: Nil.

DISTRIBUTION: S. Western Australia, South Australia, New South Wales and six localities in Victoria, Ballarat area, Warrnambool area, Rosedale area, Mallacoota area, Kentbruck area and Boneo area.

*Egernia saxatilis* Cogger 1960

SPECIMENS EXAMINED: (MUZD) The Gurdies, 8 mls. S. of Lang Lang (1). (NMV) Upper Yarra (3); Pakenham (1); Trafalgar (1).

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Warburton area (Cogger 1960) Upper Yarra; Gembrook; Tynong (Lucas & Frost 1894 as *E. striolata*).

DISTRIBUTION: Rocky outcrops along the Eastern Highlands from SE. Queensland to the Grampians Range in W. Victoria. The Gippsland form fits Cogger's (1960) subspecies *E. saxatilis intermedia*.

*Egernia whitei* (Lacepede 1804)

SPECIMENS EXAMINED: (MUZD) Cape Woolamai, Phillip Island (26); 2½ mls. N. of Darby River, Wilsons Promontory (11). (NMV) Rosedale (2); Schnapper Point (2); Cape Schanck (5).

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Upper Yarra (Lucas & Frost 1894); Rosedale; Wilsons Promontory; Schnapper Point; Upper Yarra; Mt. Dandenong (Storr 1968 as *E. whitei tenebrosa*).

DISTRIBUTION: Coastal regions and highlands of SE. Australia from Eidsvold (Qld.) to SE. South Australia, Kangaroo Island, and the Yorke and Eyre Peninsulas (S.A.). Also occurs in Tasmania and the Bass Strait islands.

*Tiliqua* Gray 1825

*Tiliqua nigrolutea* (Quoy & Gaimard 1824)

SPECIMENS EXAMINED: (MUZD) East Warburton (3); Montrose (2); Kalorama (2); The Basin, Dandenong Ranges (2); Shady Creek, N. of Warragul (1); 16 mls. NW. of Korumburra (1); 15 mls. NW. of Korumburra (1); French Island (1); Darlimurla (1); Shoreham (1); Ventnor, Phillip Island (1); Smiths Beach, Phillip Island (1); 12 mls. N. of Darby River, Wilsons Promontory (1); 7 mls. N. of Darby River, Wilsons Promontory (1); 2½ mls. N. of Tidal River, Wilsons Promontory (1); Tidal River, Wilsons Promontory (1). (NMV) Yarra Junction (1); Flinders (1).

SPECIMENS OBSERVED: 8½ mls. S. of Cumberland Junction (1 DOR); 3 mls. NE. of East Warburton (1 DOR); Kilsyth (1 DOR); Gilderoy (1 DOR); Powelltown (1 DOR); 10½ mls. ENE. of Noojee (1 DOR); 1 ml. W. of Noojee (1 DOR); 2½ mls. E. of Noojee (1 DOR); 2½ mls. SW. of Noojee (1 DOR); 1½ mls. NE. of Neerim Junction (1 DOR); 1 ml. NE. of Neerim Junction (1 DOR); Keysborough (1 DOR); Upper Beaconsfield (2); Upper Pakenham (1 DOR); 1 ml. NE. of Drouin West (1 DOR); Cranbourne (1 DOR); 1 ml. NW. of Tooradin (1 DOR); 5 mls. W. of Tooradin (1 DOR); 3 mls. E. of Tooradin (1 DOR); Moorooduc (2); 16½ mls. NW. of Korumburra (3 DOR); 13 mls. NW. of Korumburra (2 DOR); 1 ml. E. of Hiamdale (1 DOR); Sorrento (1 DOR); 2 mls. ENE. of Boneo (1 DOR); Salt Mine point, French Island (1 DOR); 3 mls. NNE. of Grantville (1 DOR); 3 mls. S. of Grantville (1 DOR); 1 ml. SW. of Cowes, Phillip Island (1 DOR); 2½ mls. W. of Rhyll, Phillip Island (1 DOR); 8 mls. NE. of The Blowhole, Phillip Island (1 DOR); 5 mls. NE. of The Blowhole, Phillip Island (2 DOR); 4½ mls. NE. of The Blowhole, Phillip Island (1 DOR); 3½ mls. NE. of the Blowhole, Phillip Island (1 DOR); 4 mls. W. of San Remo, Phillip Island (1 DOR); Cape Schank (1); 12 mls. WNW. of Foster (1 DOR); 10 mls. WNW. of Foster (2 DOR); 9 mls. WNW. of Foster (1 DOR); 7 mls. WNW. of Foster (1 DOR); 4½ mls. NW. of Foster (1 DOR); Foster area (5); 3½ mls. SSE. of Fish Creek (1); 7½ mls. NNW. of Yanakie (1 DOR); 6 mls. NNW. of Yanakie (1 DOR); 4½ mls. NNW. of Yanakie (1 DOR); 3 mls. N. of Darby River, Wilsons Promontory (1 DOR); Darby River, Wilsons Promontory (1); 3 mls. S. of Darby River, Wilsons Promontory (1 DOR); 3 mls. N. of Tidal River, Wilsons Promontory (1 DOR); 1½ mls. N. of Tidal River, Wilsons Promontory (1 DOR).

LITERATURE RECORDS: Phillip Island; Frankston (Lucas & Frost 1894).

DISTRIBUTION: Highlands of E. New South Wales and Victoria from the Blue Mountains (N.S.W.) southward, extending onto the coastal plains in W. Gippsland, SW. Victoria and SE. South Australia. Also occurs in Tasmania and the Bass Strait islands, where it is widely distributed.

*Tiliqua scincoides* (Shaw 1790)

SPECIMENS EXAMINED: (MUZD) Stratford (1). (NMV) Giffard (1).

SPECIMENS OBSERVED: Lysterfield (1 DOR); 4 mls. W. of Stratford (1 DOR); Rosebud (1).

LITERATURE RECORDS: Nil.

DISTRIBUTION: Occurs throughout N. and E. Australia inside the 20 inch isohyet, missing only the highland regions of SE. New South Wales and E. Victoria (including the S. Gippsland Highlands). *T. scincoides* does not occur any further W. than Adelaide and the Flinders Ranges (S.A.). Mitchell (1955) described the N. Australian form as a subspecies, *T. scincoides intermedia*.

VARANIDAE

*Varanus* Merrem 1820

*Varanus varius* (Shaw 1790)

SPECIMENS EXAMINED: (MUZD) Nil. (NMV) Launching Place (1); Bunyip (1); Mt. Martha (1).

SPECIMENS OBSERVED: Mt. Beenak, 1½ mls. SW. of Gilderoy (2); Tyers R., 7 mls. S. of Erieka (1).

LITERATURE RECORDS: Wallhalla; Moe; Andersons Inlet (Lucas & Frost 1894).

DISTRIBUTION: Throughout E. Australia inside the 20 inch isohyet, extending as far W. as the Mt. Lofty

Ranges (S.A.). Does not occur in the highlands of SE. New South Wales and Victoria, or in SW. Victoria.

# OPHIDIA

## ELAPIDAE

### Demansia Gray 1842

#### Demansia textilis (Dumeril & Bibron 1854)

SPECIMENS EXAMINED: (MUZD) Nil (NMV) Berlingania, Upper Yarra (1).

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Nil.

DISTRIBUTION: In E. Australia, *D. textilis* is common on the dry inland plains. The species also penetrates down the E. coast into E. Gippsland and through the Kilmore Gap into the SW. Victorian plains, but it is absent from the highlands of SE. New South Wales and Victoria (including the S. Gippsland Highlands). The range of the species to the W. is unknown, as the taxonomic status of W. populations of *Demansia* has not been determined.

### Denisonia Krefft 1869

#### Denisonia coronoides (Gunter 1858)

SPECIMENS EXAMINED: (MUZD) East Warburton (1); Pennys Saddle, 4½ mls. NE. of Loch Valley Camp (1); Mt. Baw Baw summit (1); Kalorama (2); The Basin, Dandenong Ranges (3); Upper Beaconsfield (1); Shady Creek, N. of Warragul (1); 2 mls. W. of Frankston (1); Sorrento (1); Blairgowrie (1); 1 ml. N. of Darby River, Wilsons Promontory (1); Darby River, Wilsons Promontory (1); Tidal River, Wilsons Promontory (1); Martins Hill, Lighthouse Track, Wilsons Promontory (1); Lighthouse, Wilsons Promontory (1). (NMV) Upper Yarra (1); Belgrave (2); Beaconsfield (3); Glengarry (1); Yallourn (1); Olivers Hill, Frankston (1); Western Port (1); Point Nepean (1); Darby River, Wilsons Promontory (2); Wilsons Promontory (1).

SPECIMENS OBSERVED: Waratah, Waratah Bay (2); 3 mls. S. of Darby River, Wilsons Promontory (1 DOR).

LITERATURE RECORDS: Upper Yarra (McCoy 1878 as *Hoplocephalus coronoides*).

DISTRIBUTION: Coastal and highland regions of SE. Australia from Sydney southwards to Mt. Gambier in South Australia. Also occurs on the Bass Strait islands and Tasmania.

#### Denisonia flagellum (McCoy 1878)

SPECIMENS EXAMINED: (MUZD) Nil. (NMV) Mt. Martha (1).

SPECIMENS OBSERVED: Sorrento (1).

LITERATURE RECORDS: Mt. Martha (McCoy 1878 as *Hoplocephalus flagellum*).

DISTRIBUTION: Coastal and volcanic plains of S. Central and SW. Victoria, then disjunctly in the Mt. Lofty Ranges (S.A.) and the Monaro Tableland (N.S.W.).

#### Denisonia nigrescens (Gunter 1862)

SPECIMENS EXAMINED: (MUZD) Kalorama (2);

Maffra (1); Berwick (5); Frankston (2); McCrae (2). (NMV) Belgrave (4); Mount Martha (1); South Gippsland (1).

SPECIMENS OBSERVED: Nil.

LITERATURE RECORDS: Nil.

DISTRIBUTION: Coastal region of E. Australia from Cape York (Qld.) to just E. of Melbourne.

#### Denisonia superba (Gunter 1858)

##### Highlands Form

SPECIMENS EXAMINED: (MUZD) Mt. Margaret, 5 mls. NE. of Licola (1); Nita Junction, 14½ mls. SE. of Cumberland Junction (1); 3 mls. SW. of McMahon's Creek (1); East Warburton (1); 3 mls. E. of East Warburton (2); 4 mls. ESE. of East Warburton (1); 8 mls. ENE. of Loch Valley Camp (1); 7 mls. ENE. of Loch Valley Camp (2); 6 mls. ENE. of Loch Valley Camp (1); Loch Valley Camp (3); 3 mls. NNW. of Noojee (1); 10 mls. E. of Moondarra (1). (NMV) Upper Yarra (1).

SPECIMENS OBSERVED: McMahon's Creek (1 DOR); 3½ mls. SW. of Mt. Baw Baw (1 DOR); 1½ mls. W. of Noojee (1 DOR).

LITERATURE RECORDS: Millgrove (Loveridge 1934).

DISTRIBUTION: Highlands of SE. Australia from Glen Innes, New England Tableland (N.S.W.) to Lake Mountain (Vic.). There are isolates in the Mt. Lofty Ranges and on Kangaroo Island, South Australia.

#### Denisonia superba (Gunter 1858)

##### Lowlands Form

SPECIMENS EXAMINED: (MUZD) The Basin, Dandenong Ranges (1); Pakenham (1); Maffra (5); Warragul (3); Ellinbank, 7 mls. S. of Warragul (3); Hazelwood Power Station (1); Moorooduc (2); Lang Lang (1); Darlimurla (1); McLeods Rd., French Island (1); Golf links, Phillip Island (1); Yarram (1); 2½ mls. N. of Welshpool (1); Darby River, Wilsons Promontory (2); Mt. Oberon, Wilsons Promontory (1); Sealers Cove Track, Wilsons Promontory (2); 4 mls. NW. of the Lighthouse, Wilsons Promontory (1). (NMV) Ferntree Gully (1); Mulgrave (1); Springvale (1); Gembrook (1); Berwick (1); Bunyip (6); Frankston (1); Warragul (1); Moe (1); Morwell (2); Narracan (2); Loch (2); Korumburra (2); Koala Reserve, near Rhyll, Phillip Island (1); Western Port (2); Jumbunna (3); Leongatha (1); Outtrim (5); Wilsons Promontory (1).

SPECIMENS OBSERVED: Dewhurst, 8 mls. N. of Berwick (3 DOR); 1 ml. SE. of Poowong (1 DOR); 1½ mls. SW. of Carrajung (1 DOR); 3 mls. SE. of Korumburra (1 DOR); 2 mls. NE. of Yarram (1 DOR); Cape Woolamai, Phillip Island (1 DOR); 4½ mls. NW. of Foster (1 DOR); Deep Ck., 3 mls. E. of Foster (1 DOR); 1 ml. W. of Toora (1 DOR).

LITERATURE RECORDS: Nil.

DISTRIBUTION: Highlands of S. Gippsland and coastal plains of W. Gippsland, SW. Victoria and SE. South Australia. This form also occurs on the Bass Strait islands and in Tasmania.

TABLE 1  
DISTRIBUTION PATTERNS OF WEST GIPPSLAND REPTILE SPECIES

Species	Thermal Zones occupied in West Gippsland			Zoogeographic Distribution		
	Warm Temperate Zone	Cool Temperate Zone	Cold Temperate Zone	Exclusive Bassian	Transitional from Torresian	Transitional from Eyrean
<b>CHELYIDAE</b>						
<i>Chelodina longicollis</i>	+	—	—	—	+	—
<b>AGAMIDAE</b>						
<i>Amphibolurus diemensis</i>	—	+	+	+	—	—
<i>A. muricatus</i>	+	—	—	+	—	—
<i>Physignathus lesueuri</i>	+	—	—	—	+	—
<b>SCINCIDAE</b>						
<b>LYGOSOMINAE</b>						
<i>Anotis maccoyi</i>	—	+	+	+	—	—
<i>Leiopisma delicata</i>	+	+	—	+	—	—
<i>L. entrecasteauxi</i>	—	+	+	+	—	—
<i>L. guichenoti</i>	+	+	+	+	—	—
<i>L. metallicum</i>	—	+	+	+	—	—
<i>L. mustelinum</i>	+	+	—	+	—	—
<i>L. trilineatum</i>	+	+	—	+	—	—
<i>L. weekesae?</i>	—	+	+	+	—	—
<i>Lerista bougainvilli</i>	+	+	—	+	—	—
<i>Pseudemoia spenceri</i>	—	+	+	+	—	—
<i>Sphenomorphus tympanum</i> (Cool Temperate Form)	—	+	+	+	—	—
<b>SCINCINAE</b>						
<i>Egernia luctuosa</i>	+	—	—	—	—	+
<i>E. saxatilis</i>	+	+	—	+	—	—
<i>E. whitei</i>	+	+	+	+	—	—
<i>Tiliqua nigrolutea</i>	—	+	—	+	—	—
<i>T. scincoides</i>	+	—	—	—	+	—
<b>VARANIDAE</b>						
<i>Varanus varius</i>	+	—	—	—	+	—
<b>ELAPIDAE</b>						
<i>Demansia textilis</i>	+	—	—	—	—	+
<i>Denisonia coronoides</i>	—	+	+	+	—	—
<i>D. flagellum</i>	+	—	—	+	—	—
<i>D. nigrescens</i>	+	—	—	—	+	—
<i>D. superba</i> (Highlands Form)	—	+	+	+	—	—
<i>D. superba</i> (Lowlands Form)	+	+	—	+	—	—
<i>Notechis scutatus</i>	+	+	—	+	—	—
<i>Pseudechis porphyriacus</i>	+	—	—	—	+	—
<b>TOTALS</b>	19	19	10	21	6	2

**Notechis Boulenger 1896**  
**Notechis scutatus (Peters 1861)**

SPECIMENS EXAMINED: (MUZD) East Warburton (1); 3½ mls. S. of Tooronga Falls, near Noojee (1); Olinda (1); Maffra (1); Cranbourne (1); Moorooduc (2); Mt. Oberon, Wilsons Promontory (1); Martins Hill, Lighthouse Track, Wilsons Promontory (1); Roaring Meg Ck, Wilsons Promontory (1). (NMV) Upper Yarra (1); Bunyip (1); Morwell (1); Narracan (2); Western Port (2); Korumburra (1); Jumbunna (3); Outtrim (5); Meenyan (1); Wilsons Promontory (2).

SPECIMENS OBSERVED: 3 mls. W. of Noojee (1 DOR); Morwell Power Station (1 DOR); Darby River, Wilsons Promontory (1).

LITERATURE RECORDS: Nil.

DISTRIBUTION: SE. Australia inside the 20 inch isohyet from Bunya Mountains (Qld.) to the Mt. Lofty Ranges (S.A.). A closely related species, *N. ater* occurs on Tasmania and the Bass Strait islands; the Flinders Ranges, Yorke and Eyre Peninsulas and offshore islands, South Australia; and SW. Australia (Rawlinson 1967).

**Pseudechis Wagler 1830**  
**Pseudechis porphyriacus (Shaw 1794)**

SPECIMENS EXAMINED: (MUZD) Maffra (1); 3 mls. W. of Stratford (1). (NMV) 2 mls. E. of Longford (1).

SPECIMENS OBSERVED: 11½ mls. WNW. of Stratford (1 DOR); 3½ mls. ENE. of Stratford (1 DOR); 10 mls. W. of Tyers (1 DOR); Longford (1 DOR).



LITERATURE RECORDS: Nil.

DISTRIBUTION: Coastal regions of E. Australia from Cape York (Qld.) to Morwell area (Vic.). Crosses the Eastern Highlands in Queensland and penetrates along the Murray-Darling River system into South Australia where it reaches the Mt. Lofty Ranges. Also occurs along the inland margin of the Eastern Highlands in SE. Australia, penetrating into SW. Victoria through the Kilmore Gap.

## DISCUSSION

Twenty-nine reptile species are recorded from West Gippsland in this paper, eight for the first time. For each species all the known West Gippsland localities are listed, and in addition there is a brief account of the general distribution of the species. Following the discussion of similar distributional data for East Gippsland reptiles (Rawlinson 1969) the present data can be discussed along two main lines to reach separate, but related, conclusions. This is done under two headings:

1. *Main reptile distribution patterns in West Gippsland.*

2. *The West Gippsland reptile fauna in relation to Australian zoogeographic subregions.*

Also the reptile faunas of West and East Gippsland can be compared; this is done under a third heading:

3. *Comparison of the reptile faunas of West and East Gippsland.*

Finally, the reptile fauna of Gippsland can be compared to those of the E. Bass Strait islands and Tasmania to see if there are any possible post-glacial elements (after Rawlinson 1967). This is done under a fourth heading:

4. *Comparison of the reptile fauna of Gippsland with those of the E. Bass Strait islands and Tasmania.*

Recent collecting in S. Victoria has revealed several inaccuracies in the account of the reptiles of East Gippsland, and the present paper provides an opportunity to correct them. Firstly, *Egernia luctuosa* has been collected from Seal Ck, 10 miles SW. of Mallacoota by Mr. J. H. Seebeck, adding another species to the East Gippsland reptile fauna and bringing the total number of species to 30. Secondly, the corrections to the earlier lists of reptiles of SE. and SW. Victoria (from Rawlinson 1967) need further modification: one species, *Denisonia flagellum*, can be added to the SE. Victorian list bringing the total number of species to 34; one species, *Morethia lineocellatus*, can be removed from the SW. Victorian list, and five species, *Amphibolurus diemensis*, *Leiopisma delicata*, *L. metallicum*, *L. mustelinum* and *Hemi-*

*ergis peronii*, can be added bringing the total number of species to 34. The reptilian fauna of SE. Victoria thus includes 34 species and 29 of these are known to occur in West Gippsland, the absentees being *Hemiernis decreciensis*, *Sphenomorphus tympanum* (warm temperate form), *Egernia cunninghami*, *Tiliqua casuarinae* and *Morelia argus argus*.

## 1. MAIN REPTILE DISTRIBUTION PATTERNS IN WEST GIPPSLAND.

West Gippsland can be divided into three thermal zones (warm, cool and cold temperate zones, see introduction) as a consequence of the low and high altitudes and variable nature of the climax vegetation. The locality data provided above indicates that: 10 species are restricted to the warm temperate; 1 species is restricted to the cool temperate; 8 species occur in both the warm and cool temperate; 9 species occur in both the cool and cold temperate; and 1 species occurs in the warm, cool and cold temperate (see Table 1.). This analysis of West Gippsland species agrees with their distribution in East Gippsland (Rawlinson 1969).

## 2. THE WEST GIPPSLAND REPTILE FAUNA IN RELATION TO AUSTRALIAN ZOOGEOGRAPHIC SUBREGIONS.

On the basis of animal distribution patterns, it is possible to divide the Australian continent into zoogeographic subregions, each of which has a characteristic fauna. The main subregions correspond closely to the major climatic divisions. Spencer (1896) recognized and described three such subregions, the temperate Bassian, tropical Torresian and arid Eyrean. Serventy and Whittell (1961) added a fourth "district" (or subregion), the temperate South-Western, which has a fauna consisting of Bassian and Eyrean elements with the latter predominating. These four subregions have become generally accepted as the major zoogeographic areas in Australia (Keast 1959; Littlejohn 1967; Kluge 1968; Frith 1969; Mackerras 1970) and they are almost identical to the three principal floristic zones proposed by Burbidge (1960): the Tropical zone (= Torresian); Temperate zone (= Bassian and South-Western); and the Eremaean (= Eyrean). Gippsland lies in the Bassian zoogeographic subregion (see introduction). In the account of the reptiles of East Gippsland (Rawlinson 1969), the reptile fauna was analysed using the principles for zoogeographic regions and subregions laid down by Darlington (1957) and Keast (1959) to show it is Bassian in nature. The basis for the analysis (see Rawlinson 1969 for a detailed discussion) was that as the Bassian subregion is only

partially separated from the adjacent subregions (Eyrean and Torresian) there will be complex transitions between them. The transitions cause overlapping of faunal elements with progressive subtractions in both directions. As a result of these transitions, the taxa in the Bassian (and the other subregions) can be divided into three categories:

1. *Exclusive taxa*: occur in one region only; these taxa delimit the region.
2. *Transitional taxa*: occur in two or more regions, but are extensive in one region and limited in the others.
3. *Shared taxa*: occur throughout, or are equally extensive in, two or more regions.

Thus the West Gippsland reptile fauna could contain: taxa exclusive to the Bassian; taxa transitional to, or from, the Bassian, Eyrean and Torresian; and taxa shared between the Bassian and Eyrean or Torresian. In all, it would be possible for the West Gippsland reptile fauna to contain 12 zoogeographic elements, but Table 2 shows that only 7 of these categories are represented: 3 at the specific level; 2 at the superspecific (*sensu* Mayr 1963) level; 7 at the generic level; and 3 at the familial level.

Of the 29 species recorded from West Gippsland, 21 are exclusive to the Bassian, 6 are transitional from the Torresian and 2 are transitional from the Eyrean. These are listed in Table 1. It should be noted that the species transitional from the Torresian and Eyrean are restricted to the warm temperate zone.

At the superspecific level, there are members of 3 species complexes present in West Gippsland;

2 (the *Denisonia superba* and *Notechis scutatus* complexes) are exclusive to the Bassian; and 1 (the *Sphenomorphus quoyi* complex) is transitional from the Torresian to the Bassian.

At the generic level, the West Gippsland reptile fauna has: 2 genera exclusive to the Bassian (*Notechis* and *Pseudemoia*); 1 genus transitional from the Bassian to the Torresian (*Leiopisma*); 2 genera transitional from the Torresian to the Bassian (*Chelodina* and *Anotis*); 1 genus transitional from the Eyrean to the Bassian (*Lerista*); 4 genera transitional from the Torresian and Eyrean to the Bassian (*Physignathus*, *Varanus*, *Demansia* and *Pseudechis*); 1 genus shared between the Bassian and Torresian (*Sphenomorphus*); and 4 genera shared between the Bassian, Torresian and Eyrean (*Amphibolurus*, *Egernia*, *Tiliqua* and *Denisonia*).

At the familial level, the West Gippsland reptile fauna has: 1 family transitional from the Torresian to the Bassian (Chelyidae); 1 family transitional from the Torresian and Eyrean to the Bassian (Varanidae); and 3 families shared between the Bassian, Torresian and Eyrean (Agamidae, Scincidae and Elapidae).

The above analysis of the West Gippsland reptile fauna reveals that it is essentially Bassian in nature, but the presence of the warm temperate zone has enabled certain transitional Torresian and Eyrean taxa to become established. As was the case for East Gippsland, the evidence presented indicates that it has been easier for Torresian taxa to become established in the area. These points are best exemplified at the specific level where 72% of the species are exclusively

TABLE 2  
ZOOGEOGRAPHIC ELEMENTS PRESENT IN THE WEST GIPPSLAND  
REPTILE FAUNA

Possible Distribution Pattern	Number of Taxa			
	Species	Super-Species	Genera	Families
1. Exclusive Bassian	21	2	2	—
2. Transitional Bassian to Torresian	—	—	1	—
3. Transitional Bassian to Eyrean	—	—	—	—
4. Transitional Bassian to Torresian and Eyrean	—	—	—	—
5. Transitional Torresian to Bassian	6	1	2	1
6. Transitional Eyrean to Bassian	2	—	1	—
7. Transitional Torresian and Eyrean to Bassian	—	—	4	1
8. Transitional Torresian to Eyrean and Bassian	—	—	—	—
9. Transitional Eyrean to Torresian and Bassian	—	—	—	—
10. Shared Bassian and Torresian	—	—	1	—
11. Shared Bassian and Eyrean	—	—	—	—
12. Shared Bassian and Torresian and Eyrean	—	—	4	3
TOTALS	29	3	15	5



Bassian, 21% are transitional from the Torresian, and 7% are transitional from the Eyrean. The higher taxonomic categories present a less clear picture, 2 species complexes (superspecies *sensu* Mayr 1963) are exclusively Bassian, 2 genera are exclusively Bassian and 1 genus is transitional from the Bassian to the Torresian. All other taxa are transitional from, or shared with, the Torresian or Eyrean, but a stronger link to the Torresian is evident.

### 3. COMPARISON OF THE REPTILE FAUNAS OF WEST AND EAST GIPPSLAND.

Currently, 30 species of reptiles are known to occur in East Gippsland, and 29 species are known to occur in West Gippsland. Twenty-five species are common to both areas, thus 4 West Gippsland species are missing from East Gippsland (*Leiolopisma metallicum*, *Lerista bougainvillii*, *Denisonia flagellum* and *D. superba* lowlands form), and 5 East Gippsland species are missing from West Gippsland (*Hemiergis decresiensis*, *Spheonomorphus tympanum* warm temperate form, *Egernia cunninghami*, *Tiliqua casuarinae* and *Morelia argus argus*).

It is possible to calculate the degree of faunal resemblance between these areas using Simpson's (1965) formula:

$$\text{Percentage resemblance} = \frac{100 C}{N_1}$$

where C stands for the number of taxonomic units (species or genera or families) common to the two faunas and  $N_1$  is the total number of these taxonomic units in the smaller of the two faunas. West Gippsland has the smallest fauna and application of Simpson's formula reveals that the resemblance of the West Gippsland reptile fauna to that of East Gippsland is 86% at the specific level, 93% at the generic level, and 100% at the familial level.

### 4. COMPARISON OF THE REPTILE FAUNA OF GIPPSLAND WITH THOSE OF THE E. BASS STRAIT ISLANDS AND TASMANIA.

Tasmania and the Bass Strait islands are separated from the Australian mainland by a continuous depth of less than 80 metres (Jennings 1959). Wilsons Promontory, the most southerly projection of the mainland, is included in West Gippsland and a chain of islands runs in a gentle curve from the Promontory to NE. Tasmania which lies 135 miles to the south. The major islands in this E. Bass Strait chain are situated in the Hogan, Kent and Furneaux Groups that lie 25, 50 and 85 miles respectively from Wilsons Promontory.

Bass Strait is shallowest along this E. chain

of islands, and the maximum continuous depth of 60 metres is in a channel lying between Wilsons Promontory and the Hogan Group. Moving south the water barriers between island groups get progressively shallower and the Furneaux Group is separated from Tasmania by a maximum continuous depth of only 32 metres.

The above facts are important when considering animal distribution patterns in SE. Australia in the light of climatic and sea level changes during the Pleistocene epoch. During the Pleistocene there were four major glacial phases (the Nebraskan, Kansan, Illinoian and Wisconsin) the most recent of which was divided into two further glacial phases (the Early Wisconsin and Main Wisconsin) (Ericson and Wollin 1968). During each glacial phase, surface temperatures around the earth fell by at least 5°C. (Littlejohn 1967) and the polar ice caps and continental ice sheets were greatly expanded. The vast quantity of water locked up in ice caused a eustatic drop in sea level of 70 to 100 metres. As a result of progressive accumulation of ice in the Antarctic and Greenland ice caps and sinking of the ocean floors, mean sea level has not recovered to the same extent during succeeding interglacials and it presently stands 100 metres below the Pliocene non-glacial level. (Fairbridge 1960; Schwarzbach 1963; Zeuner 1959). Thus glacial minima in sea level have dropped steadily with succeeding glaciations and the last three glacial phases (the Illinoian, Early Wisconsin and Main Wisconsin) produced minima at least 80 metres below present sea level (Fairbridge 1960). Lowering sea level to this extent would connect Tasmania and the Bass Strait islands to the Australian mainland by a landbridge (the "Bassian isthmus"), permitting faunal interchanges at a time when the climate was at least 5°C. colder than at present. The colder climate would have an important effect on reptile movements, as temperature is the major limiting factor.

The most recent glacial eustatic lowering of sea level (during the Main Wisconsin) reached its peak 17,000 years B.P. when the sea lay 100 metres below its present level. As the glacial ice melted, sea level rose rapidly from 16,000 to about 5,000 years B.P. when the present coastline was attained. Estimates are available for the rate of rise in sea level during this time (Fairbridge 1960, 1967; Godwin, Suggate and Willis 1958; Shepard 1964) and, as the maximum depths separating the present E. Bass Strait land masses are known, it is possible to obtain times for the breakup of the Bassian landbridge with the consequent isolation of the land masses:



TABLE 3

## DISTRIBUTION OF REPTILE SPECIES IN GIPPSLAND, THE E. BASS STRAIT ISLANDS AND TASMANIA

Species	Distribution				
	Gippsland	†Hogan Group	Kent Group	Furneaux Group	Tasmania
CHELYIDAE					
<i>Chelodina longicollis</i>	+	—	—	—	—
AGAMIDAE					
<i>Amphibolurus diemensis</i>	+	—	—	+	+
<i>A. muricatus</i>	+	—	—	—	—
<i>Physignathus lesueuri</i>	+	—	—	—	—
SCINCIDAE					
LYGOSOMINAE					
<i>Anotis maccoyi</i>	+	—	—	—	—
<i>Hemiergis decresiensis</i>	+	—	—	—	—
<i>Leiopisma delicata</i>	+	—	—	—	+
<i>L. entrecasteauxi</i>	+	+	—	+	+
<i>L. guichenoti</i>	+	—	—	—	—
<i>L. metallicum</i>	+	+	+	+	+
<i>L. mustelinum</i>	+	—	—	—	—
<i>L. ocellatum</i>	—	—	—	+	+
<i>L. pretiosum</i> (Form A)	—	—	—	+	+
<i>L. pretiosum</i> (Form B)	—	—	—	—	+
<i>L. trilineatum</i>	+	+	+	+	+
<i>L. weekesae</i> ?	+	—	—	—	—
<i>Lerista bougainvilli</i>	+	—	+	+	+
<i>Pseudemoia speneeri</i>	+	—	—	—	—
<i>Sphenomorphus tympanum</i> (Cool Temperate Form)	+	—	—	—	—
<i>Sphenomorphus tympanum</i> (Warm Temperate Form)	+	—	—	—	—
SCINCINAE					
<i>Egernia cunninghami</i>	+	—	—	—	—
<i>E. luctuosa</i>	+	—	—	—	—
<i>E. saxatilis</i>	+	—	—	—	—
<i>E. whitei</i>	+	+	+	+	+
<i>Tiliqua casuarinae</i>	+	—	—	—	+
<i>T. nigrolutea</i>	+	+	+	+	+
<i>T. seincoides</i>	+	—	—	—	—
VARANIDAE					
<i>Varanus varius</i>	+	—	—	—	—
BOIDAE					
<i>Morelia argus argus</i>	+	—	—	—	—
ELAPIDAE					
<i>Demansia textilis</i>	+	—	—	—	—
<i>Denisonia coronoides</i>	+	—	+	+	+
<i>D. flagellum</i>	+	—	—	—	—
<i>D. nigrescens</i>	+	—	—	—	—
<i>D. superba</i> (Lowlands Form)	+	—	—	+	+
<i>D. superba</i> (Highlands Form)	+	—	—	—	—
* <i>Notechis ater</i>	—	—	—	+	+
<i>N. scutatus</i>	+	—	—	—	—
<i>Pseudechis porphyriacus</i>	+	—	—	—	—
TOTALS	34	5	6	12	15

\* This species, *Notechis ater*, does not occur in S. Victoria; however it does occur on the Australian mainland in South Australia and Western Australia (Rawlinson 1967).

† Data on the reptiles of the Hogan Group by courtesy of Mr B. S. McIntosh, Zoology Department, University of Tasmania.

## Years B.P.

17,000	Sea level 100 metres lower than at present.
16,000	Eustatic rise in sea level commenced.
12,750	Sea level 60 metres lower than present. Wilsons Promontory isolated from Hogan, Kent and Furneaux Groups and Tasmania.
10,000	Sea level 32 metres lower than at present, Furneaux Group isolated from Tasmania.

Thus Tasmania and the E. Bass Strait islands were isolated from the Australian mainland 12,750 years ago when the climate was colder. The reptile faunas of Tasmania and the Bass Strait islands then should be similar in composition to, or relicts of, the fauna occupying the landbridge area at the time of isolation. Consequently, comparison of the Gippsland reptile fauna with those of the E. Bass Strait islands and Tasmania could reveal the presence of post-glacial intrusives.

Five reptile species are known to occur in the Hogan Group, 6 species in the Kent Group and 12 species in the Furneaux Group; all these species are shared with Tasmania which has 15 species. However 3 species from the Furneaux Group are not shared with Gippsland which has 34 species (Table 3.). Thus the reptile faunas of the E. Bass Strait islands are apparently derived from the same source and they are closely allied to the present day Tasmanian reptile fauna (see also Rawlinson 1967).

Thirty-four reptile species occur in Gippsland, 5 are shared with the Hogan Group, 6 with the Kent Group, 9 with the Furneaux Group and 11 with Tasmania (Table 3.). Therefore there are 23 possible post-glacial intrusives (Rawlinson 1967), but only those found in the areas closest to the old landbridge (i.e. in the cool and cold temperate zones) can be classified as probable post-glacial intrusives, especially if they occur in the Wilsons Promontory or Cape Otway areas. Only 7 of the 23 species fit into this category, they are: *Anotis maccoyi*, *Leiopisma guichenoti*, *L. mustelinum*, *L. weekesae*?, *Pseudemoia spenceri*, *Sphenomorphus tympanum* (cool temperate form) and *Notechis scutatus*. It is considered that if they showed their present distributions when the Bassian landbridge was present, they would have reached Tasmania.

The remaining 16 species occurring in Gippsland but not in Tasmania are primarily forms whose main distributions lie outside S. Victoria, and their present distributions (mainly in the warm temperate) would have excluded them

from the landbridge. They may be classified as being of E. or W. origin according to whether the species has a generally E. or W. distribution (Rawlinson 1967). There are 12 such E. forms and 4 W. forms: the E. group includes *Chelodina longicollis*, *Amphibolurus muricatus*, *Physignathus lesueuri*, *Sphenomorphus tympanum* (warm temperate form), *Egernia cunninghami*, *E. saxatilis*, *Tiliqua scincoides*, *Varanus varius*, *Morelia argus argus*, *Denisonia nigrescens*, *D. superba* (highland form), and *Pseudechis porphyriacus*; and the W. group includes *Hemiergis decresiensis*, *Egernia luctuosa*, *Deinania textilis* and *Denisonia flagellum*.

Thus it can be seen that there has been a change in the Gippsland reptile fauna over the last 12,750 years, and 7 species (including some of the dominant present day S. Victorian species) are apparently post-glacial intrusives.

## CONCLUSIONS

1. West Gippsland can be divided into three thermal zones, the warm, cool and cold temperate zones, each of which has its own reptilian fauna.

2. Following the principles for zoogeographic regions and subregions laid down by Darlington (1957) and Keast (1959), the West Gippsland reptile fauna is considered to be Bassian in nature, but the warm temperate zone has enabled transitional Torresian and Eyrean taxa to become established.

3. Using Simpson's (1965) method for assessing faunal resemblance, the West and East Gippsland reptile faunas are closely related.

4. At least 7 of the Gippsland reptile species are post-glacial intrusives.

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## THE EUCALYPT ASH RESOURCE OF WEST GIPPSLAND

By S. C. BUTLER\*

**ABSTRACT:** The paper describes the natural occurrence and characteristics of the ash type eucalypts of West Gippsland. The effects of settlement, fire and utilization on the original resource are discussed.

Measures being taken by the Forests Commission of Victoria to conserve and increase the resource are outlined. These include the regeneration of logged areas, the reforestation of previous ash areas now carrying bracken and scrub, the thinning of regrowth stands, and intensified fire protection.

The future use and value of the ash resource is discussed.

### INTRODUCTION

The name 'ash' was applied to a small group of eucalypts in the early days of settlement of Australia, because of a superficial resemblance of the timber to that of the European ash (*Fraxinus* spp).

In Victoria the ash type eucalypts are confined to the cool high rainfall areas of the Central and Eastern Highlands, and the Otway and South Gippsland Ranges. The total State Forest area in Victoria is about 14,500,000 acres, and only 636,000 acres of this is classified as ash type country. Despite their limited distribution the ash species are of major importance in Victorian forestry.

### OCCURRENCE OF ASH SPECIES IN WEST GIPPSLAND

For the purpose of this paper West Gippsland is considered as the area covered by the Dandenong, Neerim, Erica, Yarram and Mirboo Forest Districts. This area coincides approximately with the West Gippsland Region, and was used in compiling the forest statistics for the Regional Resources Survey.

Ash group species occurring naturally in West Gippsland are mountain ash (*Eucalyptus regnans*, F. Muell.), alpine ash (*E. delegatensis*, R. J. Baker), and shining gum (*E. nitens*, Maiden). They are all found in the Central Highlands in the headwaters of the Bunyip, Tarago, Latrobe, Toorongo, Tanjil, Thomson and Aberfeldy Rivers, but only mountain ash occurs in the South Gippsland Ranges, which have a maximum height of

some 2,200 ft above sea level. Fig. I shows the distribution of the ash resource in West Gippsland.

Of the 950,000 acres of State Forest in West Gippsland about 167,000 acres is classified as ash country. Much of this is steep and broken, with generally deep moist fertile soils. The predominant rock formations are the granitic northern highlands with Cretaceous mudstones and shales in South Gippsland.

The ash zone extends from about 1,500-4,000 ft above sea level, with extremes down to 600 ft and up to about 4,500 ft. The best forest development is on the cooler and moister southern slopes. Below the ash zone eucalypts of the sclerophyllous stringybark-peppermint-gum type take over whilst at higher levels in the alpine zone, a sparser tree vegetation merges into high-plain grassland swamps and rocky outcrops (Ferguson 1965).

### ASH TYPE FOREST DESCRIPTION

The ash species occur mainly in even-aged stands of one species only. Mountain ash reaches its best development between 1,500 and 3,500 ft above sea level, but extends down to some 600 ft on sheltered sites. At its upper limits it is replaced by alpine ash, found mainly between 3,000 and 4,500 ft but reaching a maximum altitude of around 5,000 ft. Shining gum also occurs at the higher levels.

At the lower elevations the undergrowth is hygrophylous in character and very luxuriant. Larger shrubs and trees such as blackwood (*Aca-*

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FIG. 1

*cia melanoxyton*, R. Br.), myrtle beech (*Nothofagus cunninghamii*, Hook (Oerst)), and sassafras (*Atherosperma moschatum*, Labill) frequently form the second storey, to a dense lower storey of tree ferns and moisture loving shrubs. Towards the upper reaches, particularly in the alpine ash areas, the undergrowth is much sparser.

### SPECIES CHARACTERISTICS

Trees of the ash species, and particularly mountain ash, grow to great heights, although of comparatively slender girths. Hardy (1921) lists a number of mountain ash trees well over 300 ft high, including 342 ft to a broken top in the Dandenongs, 319 ft in the Otways, and 326 ft at Mt. Baw Baw. However these trees are no longer standing, and possibly there are no trees left in West Gippsland exceeding 300 ft.

The ash species grow rapidly, and typical

heights for mountain ash on better sites are 35 ft at 4 years old, 59 ft at 10 years. Some of the faster growing trees of the regrowth from the 1939 fires are now around 160 ft high. Well-stocked mountain ash stands on favourable sites will grow at the rate of more than 300 cu. ft per acre annually, and more than 20,000 cu. ft per acre in mill logs has been harvested from some of the older original stands.

Unlike the majority of the eucalypts, the ash species do not develop ligno-tubers, and mountain ash and alpine ash do not coppice. The species are readily killed by fires, but provided adequate seed is available on the trees, fires will normally produce excellent natural regeneration. However repeated fires at short intervals can wipe out ash stands, by killing the regeneration before it is old enough to carry viable seed.

Often tens of thousands of seedlings per acre

result from fires, but natural thinning rapidly reduces these heavy initial stockings. Britton (1954) states that a stocking of about 1,140 trees per acre at age 10 years will reduce to 485 at 20, 290 at 30, and 150 at 50 years.

## HISTORY OF THE ASH FORESTS

The original extensive ash stands of West Gippsland have been changed considerably by settlement, fires and utilization.

### 1. SETTLEMENT

From 1880 to about 1900 extensive mountain ash areas north of Noojee and in the Strzelecki Ranges of South Gippsland were sub-divided and made available for settlement. In an astonishingly short time tens of thousands of acres were cleared: the timber was considered a nuisance by the settlers and destroyed, generally by burning. Much of this ash country was later abandoned since problems of scrub, vermin, difficult topography, fire and isolation proved too much for the pioneers.

Limited areas of these abandoned blocks now carry mountain ash regrowth resulting from clearing fires or wild fires, but in general the vegetation ranges from bracken (*Pteridium esculentum*, Forest.f.) and low scrub to stands of wattles up to 50 ft in height and with diameters 9 inches or more. The wattles generally form a dominant overstorey, with lesser scrub species below the main canopy. The most common are silver wattle (*Acacia dealbata*, Link) and hickory wattle (*Acacia obliquinervia*, M. D. Tindale) with blackwood (*Acacia melanoxylon*, R. Br.) in the gullies. In the South Gippsland Ranges blackberries (*Rubus* spp.) are widespread.

Some of these abandoned blocks reverted to the ownership of the Crown, and since the 1930s the Forests Commission has been purchasing blocks which remained freehold. To date tens of thousands of acres, which should never have been made available for selection, have been acquired.

### 2. FIRES

Over the years bush fires have caused tremendous losses in the ash forests of West Gippsland. These include Black Thursday in 1851 and the big fires of 1898, 1926 and 1932, and culminate in the catastrophe of January 1939 when 71 lives were lost, townships obliterated, and throughout Victoria 3½ million acres of State Forest destroyed or damaged. 'For mile upon mile the former forest monarchs were lain in confusion, burnt, torn from the earth, and piled one upon another as matches strewn by a giant hand'. (Royal Commissioner in Report of Royal Commission, 1939).

The earlier fires produced some extensive areas

of excellent ash regeneration, but most of these were destroyed by the 1939 fires. In their turn the 1939 fires resulted in some 96,000 acres of ash regeneration in West Gippsland, but left only about 17,000 acres of green ash forest in the region.

### 3. UTILIZATION

From the early days of settlement ash timbers were eagerly sought for palings and shingles because they split so readily, and many of the original giants fell to the axes of the paling splitters. Despite their ease of working and sawing they were not in great demand for milling, because of the tendency of the sawn timber to collapse and distort during drying and seasoning. Milling was concentrated in the slower-growing, more durable, species of the foothill forests.

Following advances in seasoning techniques from about 1910 onwards, and the development of a process for the 'reconditioning' of collapsed ash timber, the success of kiln-seasoned ash was assured (Galbraith 1937). Reconditioning consists of steam heating the partially dried timber, and this restores the original shape and removes all stresses.

Large scale milling of ash forests commenced in the Warburton area, and extended in the early twenties to the mountain ash forests north of Noojee and Erica. Because of their attractive appearance, light colour, and freedom from gum veins and other blemishes ash timbers became widely used for furniture and cabinet work, joinery, flooring, and weatherboards.

The ash mills and associated settlements were mainly located in the forests, with supplies brought in and timber carted out over tramways. These ranged from wooden lines and horse-drawn trucks to more elaborate steel tramlines with steam locomotives. Logging of the huge trees in the difficult country was beyond the ability of the horses and bullocks previously used, and large stationary steam winches were introduced.

These logging operations left large quantities of lower quality material considered useless for sawing. Following an investigation by the Forests Commission of the quantities of timber suitable for pulpwood available from these residues and other sources, in 1936 the firm of Australian Paper Manufacturers Ltd. decided to build a chemical pulp mill at Maryvale, near Traralgon. The first deliveries of pulpwood to the mill were made in October 1937.

The ash timbers have a number of desirable properties for the production of wood pulp. For hardwoods their fibres are comparatively long, and a favourable length/diameter ratio in the fibres results in the production of strong, opaque



paper. The light colour of the wood lessens the costs of pulping and of bleaching. In comparison with softwoods they give a comparatively high yield of pulp.

By the late 1930s the sawmills had almost cut out the more accessible areas of mature mountain ash, and the Forests Commission and the timber industry started to build roads into hitherto inaccessible ash areas, including the Toorongo Plateau and the Eastern and Western Tanjil Valleys. The building of roads, instead of tramlines, was made possible by the use of the newly introduced crawler tractors.

This work was soon interrupted by the disastrous 1939 fires. The Forests Commission immediately initiated action to minimise the loss of fire-killed timber: the main measures were the acceleration of milling operations, transfer of these operations from the remaining green timber to fire-killed stands, and the felling and preservation for later milling of timber which could not be utilized quickly.

Despite the problems created by the 1939-45 war the main aims of this salvage scheme were achieved. At the height of operations in 1946/47, more than 6 million cubic feet of fire-killed ash logs were cut in West Gippsland, and large quantities of lower grade timber were supplied to the pulpwood mill at Maryvale. In addition to its advantages for road building, the crawler tractor was of tremendous assistance in logging the fire-killed stands, since it provided much greater flexibility than the winches.

Because of the progressive degrade of the fire-killed timber and the increasing damage to the 1939 fire regeneration, logging of the dead timber was discontinued in the early 50s. This followed a Forests Commission decision that future sawmills should be located in centres of population outside the forest. Hence this period saw a considerable drop in the number of bush mills.

As the supplies of fire-killed timber cut out, the limited green ash stands left in West Gippsland were unable to keep all the mills going, and some moved further east into the green, predominantly alpine ash areas.

By 1967/68 the West Gippsland ash sawlog output was only some 700,000 cu. ft, and in 1968/69 this fell to 600,000 cu. ft, with the main logging areas in the eastern Strzeleckis and the head of the Aberfeldy River. The eastern Strzeleckis timber is mainly small patches of mountain ash about 60 years old resulting from early attempts at settlement, and the Aberfeldy River timber is a previously untouched area of mainly alpine ash near the Great Dividing Range.

The ash pulpwood output from West Gippsland State Forest in 1968/69 was 1,900,000 cu. ft, mainly from logging residues, plus a limited volume from clearing for plantation establishment and from thinning in 1939 regrowth stands.

### PRESENT CONDITION OF ASH TYPE STANDS

The following table sets out the present extent of the various types of vegetation on the ash State Forest areas of West Gippsland.

	acres
Virgin ash stands	2,500
Pre 1939 ash regrowth stands	6,000
1939 ash regrowth stands	96,000
Green ash stands logged since 1939	8,500
Ash plantations	6,000
Scrub and bracken areas	48,000
Total	167,000

About 50% of the 96,000 acres of 1939 regrowth is mountain ash, and this West Gippsland regrowth is part of a State total of 278,000 acres of ash regrowth resulting from the 1939 fires.

The numerous fires up to 1939 hindered until the early 1950s recognition of the general failure of logged ash stands to regenerate satisfactorily in the absence of fire, and over 5,000 acres of the green ash logged since 1939 is poorly regenerated.

### FOREST MANAGEMENT POLICY

The Forests Commission's basic aim is to secure for the community maximum benefits from land reserved for forestry purposes. The primary objective is to develop the forest resources to produce the maximum volume of high quality timber, but management caters for water conservation and other legitimate uses of forest land in conjunction with timber production (Ferguson 1965).

Because of their fast growth and high quality timber the ash forests are of major importance in the achievement of maximum timber values. The ash areas near Melbourne, including those in West Gippsland, are of particular economic value because log royalties are higher the nearer the site to Melbourne, and all the West Gippsland ash is within the zone of economic pulpwood supply for the Maryvale mill.

Forests Commission activities aimed at obtaining increased timber benefits from the West Gippsland ash forests are 1. Regeneration of areas as they are felled for timber production. 2. Reforestation of scrub and bracken areas. 3. Thinning of regrowth stands. 4. Protection from fire and other destructive agencies.



## 1. REGENERATION OF FELLED AREAS

Following the realization in the early 1950s that many logged ash stands were not regenerating satisfactorily, research work by Ashton (1956), Grose (1957), and Cunningham (1960) defined the main requirements for successful seedling establishment as a receptive seed-bed which favours germination and promotes rapid early growth, and an adequate seed supply.

Techniques developed to satisfy these requirements are being used to regenerate the area of some 300 acres of ash forest clear-felled annually in West Gippsland.

Although on the more exposed aspects the soil disturbance from logging may produce an acceptable seed-bed, where possible the seed-bed is made highly receptive by the autumn burning of the heads and other debris from the logging. This is found to improve germination, and rapid growth of seedlings with better survival.

The burning of the debris requires sound planning and a good knowledge of fire behaviour, if the objectives are to be achieved without unacceptable damage to adjoining forest areas. Utilization must be organized to produce cut-over areas with suitable characteristics for burning, and there is only a relatively short period when satisfactory safe burns can be carried out.

The efficiency of the seed-bed decreases rapidly, and the seed should be supplied as soon as possible after the bed has been prepared. The relatively small areas being logged in West Gippsland are normally hand sown, at the rate of about 50,000 viable seeds per acre for alpine ash sites, and 90,000 per acre for mountain ash, with the aim of establishing some 1,000 well distributed seedlings per acre. This sowing rate is equivalent to about 1-1½ lbs of seed per acre, depending on the percentage of viable seeds.

Before sowing the seeds are coated with clay to give a larger sized particle which results in more even distribution, and an insecticide and fungicide are included in the coating. Harvesting by insects can result in significant losses if the seed is not treated. The coated seeds are dyed yellow to facilitate ground checks of particle dispersion.

For large areas aerial sowing is cheaper and much quicker than hand sowing, and so is widely used in the more extensive regeneration operations in East Gippsland.

Techniques have been developed for the economic collection of the comparatively large quantities of seed required by artificial sowing. Direct costs for the collection of alpine ash seed are now about \$4-\$6 per pound, and for mountain ash from \$7-\$9 per pound. Shining gum seed is

rarely available in quantity and is comparatively costly to collect. The size of the area and local factors can result in wide variations in the cost of artificial sowing, but typical costs, including burning and seed collection, are around \$11-\$17 per acre.

When necessary, browsing animals are controlled by baiting with carrots treated with 1080 poison.

In general the use of deliberately retained trees as a seed source has been abandoned as unsatisfactory. Difficulties include the irregularity of good seed trees, limited natural seed fall, and the hazard of inducing the shedding of seed when the seed-bed is most 'receptive'. Also the retention of merchantable trees as a seed source can result in a substantial loss of royalty.

## 2. REFORESTATION OF SCRUB AND BRACKEN AREAS

The difficulties of preparing a satisfactory seed-bed limit the use of direct seeding on these areas, and in general in West Gippsland they are being planted with seedlings.

Forests Commission planting started in 1940 on areas north of Noojee, but the bulk of recent work has been in the eastern Strzeleckis. The total area established to date is some 6,000 acres, virtually all mountain ash, and planting is proceeding at the rate of about 750 acres per year. In the eastern Strzeleckis use is being made of prison labour from two penal camps.

A.P.M. Forests Pty. Ltd. (a subsidiary of Australian Paper Manufacturers Ltd.) is also carrying out large-scale mountain ash planting in the eastern Strzeleckis, with about 6,000 acres established to date. Part of this planting is on State Reserved Forest over which the Company has been granted a long term lease.

To allow access for planting and to reduce early competition with the plants, the scrub is first removed or greatly reduced. As far as possible this is done with tractors, although on the steeper country the scrub must be hand-felled and burned. The dense wattle stands present a special problem, because in general the trees have no merchantable value, and if they are felled when green a tremendous volume of debris is produced. The Forests Commission's present procedure is to clear planting strips through them, and to ringbark the wattles in between these strips.

Experimental work is being carried out on aerial spraying of the dense wattle stands with herbicides, mainly the butyl ester of 245T in fuel oil. Results to date are promising, as once trees

have been defoliated it is much easier to handle the remaining dead material.

Unlike pines, open-rooted ash stock are very difficult to plant out, and the plants are raised in individual small containers. At the age of about 9 months and some 9 in. to 12 in. high, the seedlings are planted out in the winter and early spring at the rate of about 600–700 plants per acre. Because of the limited number of trees which attack the young trees is essential, and this is achieved by the use of aerial poisoning with earrots treated with the poison 1080. Fertilizers are being used to stimulate the early growth of the plants, with the aim of minimising effects of competition from the quickly returning scrub, and reducing vermin damage.

Although of proven effectiveness and requiring only limited quantities of seed, planting is costly and presents problems on the higher country where the winter weather is often unsuitable for work. Research is being carried out on possible methods of reforesting scrub and bracken areas by direct seeding, and under some conditions soil cultivation has produced a satisfactory seed bed.

Direct seeding would give greater flexibility since aerial sowing could be used. This would be much cheaper, as experience to date indicates costs for this sowing could be in the order of \$55 per acre as against \$90 per acre for planting. However the seed requirements would be some 30 times that for planting.

Although it may not be practical to reforest all the scrub and bracken areas, obviously the present reforestation rate of about 750 acres per annum is undesirably low. Commonwealth Government financial assistance, on the same lines as has been provided for the softwood planting programme, is being sought, with the aim of increasing the annual ash reforestation programme within 100 miles of Melbourne to 5,000 acres per annum. Of this about 2,500 acres per annum would be in West Gippsland.

### 3. THINNING OF REGROWTH STANDS

Ash regrowth stands are being thinned commercially at the rate of about 100 acres annually, with some 400 acres treated to date. The main product is pulpwood. The poorer trees are removed, with the aim of increasing the growth rate of the better quality retained trees and reducing the time required to produce high quality saw logs.

On the basis of present techniques it is doubtful whether this operation can be greatly expanded, because it must be restricted to the easier topography to avoid damage to the retained trees and high production costs.

### 4. FOREST PROTECTION

Destructive fires have been part of the history of the ash forests, and if considered an inevitable part this situation would seem to make a substantial expenditure on improving these forests a doubtful investment.

Complete freedom from fires is impossible, but fire protection advances since 1939 have greatly reduced the risk of large-scale damage. The devastating fires of the past started in the dry foothill forests on the western and northern fringes of the ash forests. Hundreds of miles of roads and tracks have been built in this marginal country and men and equipment can be moved quickly to any outbreaks. Fuel-reduction burning is used with the aim of keeping ground fuel down to a safe level.

Lookout towers have been established, and when necessary aircraft are used to supplement these towers on fire spotting. Helipads have been built in the more remote areas so that men can be moved in rapidly by helicopter.

Dams for storing water have been built, wireless communications installed, and major items of fire fighting equipment such as 'dozers, tankers and other types of vehicles are readily available.

Of recent concern is the defoliation of some mountain ash regrowth stands in the headwaters of the Tarago and Bunyip Rivers by a phasmid—*Didymuria virescens*. This is a native stick insect which occurs widely throughout the north-east of Victoria, and aerial spraying with malathion is being used as a control measure.

### FUTURE OF THE ASH FORESTS OF WEST GIPPSLAND

These forests will become of increasing importance in helping to meet the wood requirements of the Region and the State. The Region's present total ash timber output of about 2½ million cu. ft annually is considerably less than the estimated total annual increment for the regrowth and planted ash stands, which is about 20 million cu. ft.

This low output is due to the limited volumes of timber available from the dwindling resource of virgin stands and older regrowth stands, and not to lack of demand. In fact there is an increasing demand for ash saw-logs and ash pulpwood.

The sawmillers of the region cut about 3 million cu. ft of mixed species logs from foothill forests in 1968/69, and as this resource is becoming exhausted the industry is looking to the ash forests for future supplies. Also the Maryvale pulp mill, which used 6 million cu. ft of ash pulpwood in 1968/69, is seeking increased supplies, particularly of regrowth ash.



The remaining virgin stands and older regrowth stands will be felled over the next decade, and clear-felling in the 1939 regrowth will be necessary if the demands for supplies are to be met. An early start on fellings will fit in with 'rotations' of around an average of 60 years for mountain ash, and 80 years for the slower growing alpine ash and shining gum.

The original stands logged for milling were at least 100 years old, and often considerably more, but the proposed shorter rotations will make the economics of ash plantations more attractive, produce logs of more convenient size, and reduce losses from decay.

On the basis of the present planting plan and spreading the cut over 60 years, clear-fellings in the 1939 regrowth could be commenced in about 10 years at an annual rate of 1,800 acres. This could be increased to 2,200 acres if the proposed expanded reforestation programme is undertaken.

Clear-felling of 1,800 acres annually at the age of 40 years should produce some 4 million cu. ft of saw-logs and a somewhat larger quantity of pulpwood, increasing to about 7 million cu. ft of saw logs plus a similar quantity of pulpwood when fellings are in 60 year old stands. The efficient utilization of these saw-logs will require improved conversion equipment and techniques, and much larger mills than those now operating in the Region.

An indication of the industrial activity which will result from the utilization of the timber from the regrowth stands is that, on the basis of current prices, the green sawn timber and wood pulp produced will have a value in the order of \$10,000,000 annually at the 'ex-mill' stage.

The ash forests provide the vegetative cover for the upper reaches of a number of important domestic and industrial water supply catchments in West Gippsland, including the Bunyip and Targo Rivers, the Latrobe River and its tributaries, the Thomson River and several short streams which rise in the eastern Strzeleckis and flow to the sea.

Forest operations in these catchments will con-

tinue to be organized, controlled and conducted in such manner as will adequately protect water supply interests.

In accordance with Forests Commission policy of multiple use of forest lands, future management of the ash forests of West Gippsland will cater for public recreation and tourism. These spectacular forests are located near concentrations of population in Melbourne and the Latrobe Valley, and public and Forests Commission roads provide ready access.

## ACKNOWLEDGMENTS

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# THE FUEL AND POWER RESOURCES OF THE WEST GIPPSLAND REGION

By C. S. GLOE\*

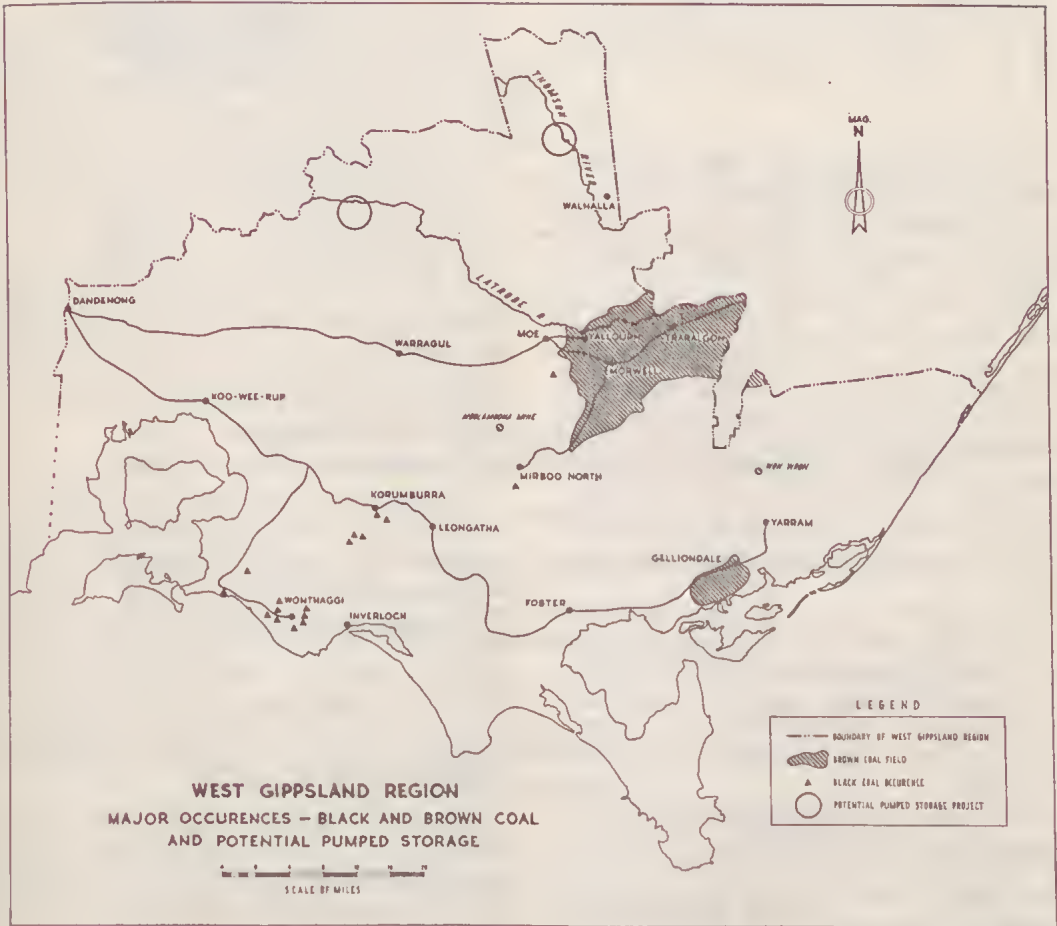


FIG. 1

## INTRODUCTION

Readily available indigenous fuels have played an important part in the high level of industrial development achieved in Victoria. Those fuels concerned are the hard or black coals of South Gippsland and the brown coals of the Latrobe

Valley—two areas occurring within the West Gippsland Region.

Just offshore from the West Gippsland Region and extending to the east is the Gippsland Basin in which significant finds of oil and gas have been made over the last few years.

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Prior to 1910, local firewood and black coal from New South Wales were the chief fuels used to provide energy for power, heat, transport, etc., in Victoria. Following a prolonged strike of miners in the Newcastle field of New South Wales, the State Coal Mine of Wonthaggi was opened in 1909. Up until 1930 some 11,000,000 tons of black coal were obtained from this source and ensured a supply of coal for the Victorian Railways.

Over the past 40 years the opening up and development of the brown coal deposits in the Latrobe Valley has played a dominant role in meeting the energy requirements of Victoria (Chapman, 1967). It is likely that this fuel, together with the newly discovered oil and gas, will provide the basis for the continued growth of Victoria for many years to come.

## BLACK COAL

The principal localities where black coal has been mined in the West Gippsland Region are Wonthaggi, Korumburra, Jumbunna, Outtrim, Kileunda, Woolamai, Berry's Creek, Boolarra and Coalville (Thomas, 1968.) (Fig. 1.)

The coal occurs in Mesozoic rocks, which according to recent palynological investigations are now considered to be of Lower Cretaceous age. It would appear that the coals developed in a number of discrete basins of sedimentation. They are interbedded with felspathic sandstones and mudstones, both of which exhibit current bedding. Edwards, Baker and Knight (1944) favoured a drift origin for the coal although it was considered that some in-situ growth could also have occurred.

These are banded bituminous coals with medium moisture contents, but relatively high ash contents. Although less efficient than the coals of Newcastle, the Gippsland coals are generally good steaming coals. They are, however, unsuitable for gas making, and, with minor exceptions, are non-coking.

Apart from the question of quality, the Gippsland coals proved more expensive to mine than the New South Wales coals. Two main reasons were the general thinness of the seams and the extensiveness of faulting. The latter produced fault-bound blocks, each of which had to be mined as separate units, but, in addition, resulted in numerous lesser displacements throughout each block.

Because of the high production costs, the coal mines were closed down in 1968, and at that time the total black coal production in Victoria had reached 22,338,000 tons. Most of the coal was mined between 1910 and 1930, during which time rates of production ranged from about

400,000 to just over 700,000 tons per annum. After 1930, production rates gradually declined. It has been estimated that reserves at Wonthaggi total 6,660,000 tons. In other areas total reserves are estimated at 2,340,000 tons.

The State Coal Mine was reopened in 1969 by private interests, but the quantities of coal being mined are small.

The black coals of South Gippsland were used mainly by the Railway Department of Victoria. Some coal was burned in power stations such as Newport and Wonthaggi, and it was used also for industrial and domestic purposes.

## BROWN COAL

The major deposits of brown coal in the West Gippsland Region are located in the Latrobe Valley and in the Gelliondale-Welshpool area (Fig. 1). Lesser deposits have been reported from a number of localities (Thomas and Baragwanath, 1949) but the only attempt at exploitation has been from the Thorpdale-Childers area.

### LATROBE VALLEY

In the Latrobe Valley Depression thick brown coal seams of the Upper Latrobe Valley Coal Measures underlie an area from 5 to 10 miles wide extending over a length of more than 30 miles from near Yallourn in the west to just south of Sale in the east. Much of this area falls within the West Gippsland Region.

### GEOLOGY

The detailed stratigraphy and structure of the Upper Latrobe Valley Coal Measures within this coal field have been described by Thomas and Baragwanath (1949-1951), Gloe (1960, 1967). This sequence of sediments has a thickness of about 2,200 ft in the eastern portion of the Depression where all three seams or groups of seams are fully represented. However, in the Yallourn-Morwell area the lowermost or Traralgon group of seams is missing and the section is only some 1,500 feet thick.

The complex splitting of the Morwell group of seams in the Yallourn-Morwell Field is shown in the diagrammatic section (Fig. 3). The relationship of the individual open cuts and the coal seam in which they are being operated is also shown.

### EARLY INVESTIGATIONS

Only two outcrops of coal seams from the Upper Latrobe Valley Coal Measures are known in the Latrobe Valley, and both are located near Yallourn. One, known as Davis's Seam, occurs well above river level in the Latrobe River gorge about one mile upstream from the Yallourn Power Station, and was worked in 1874. The sec-



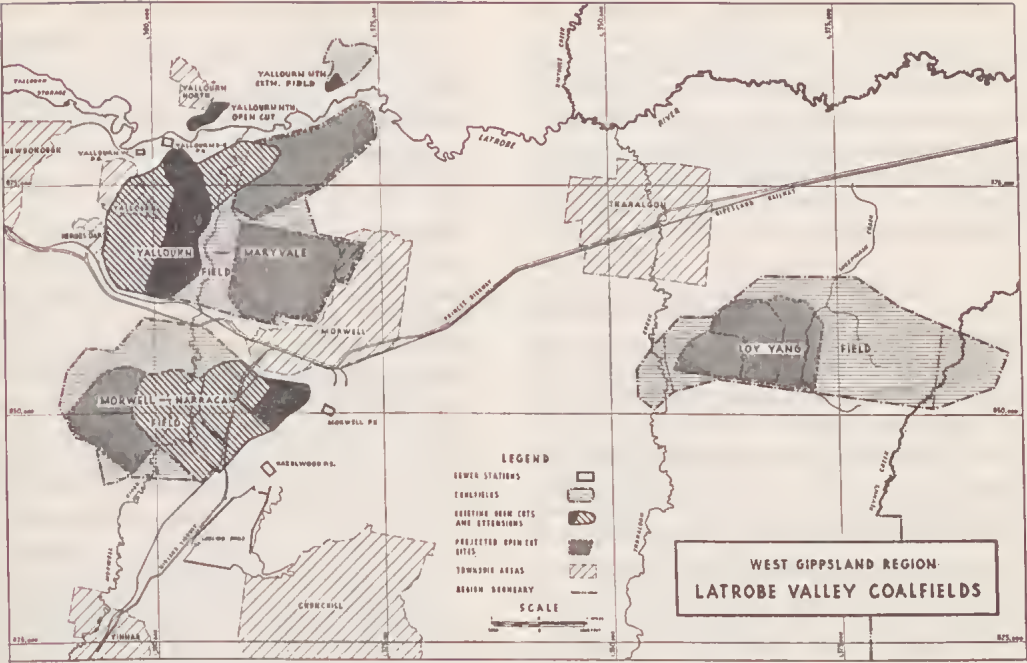
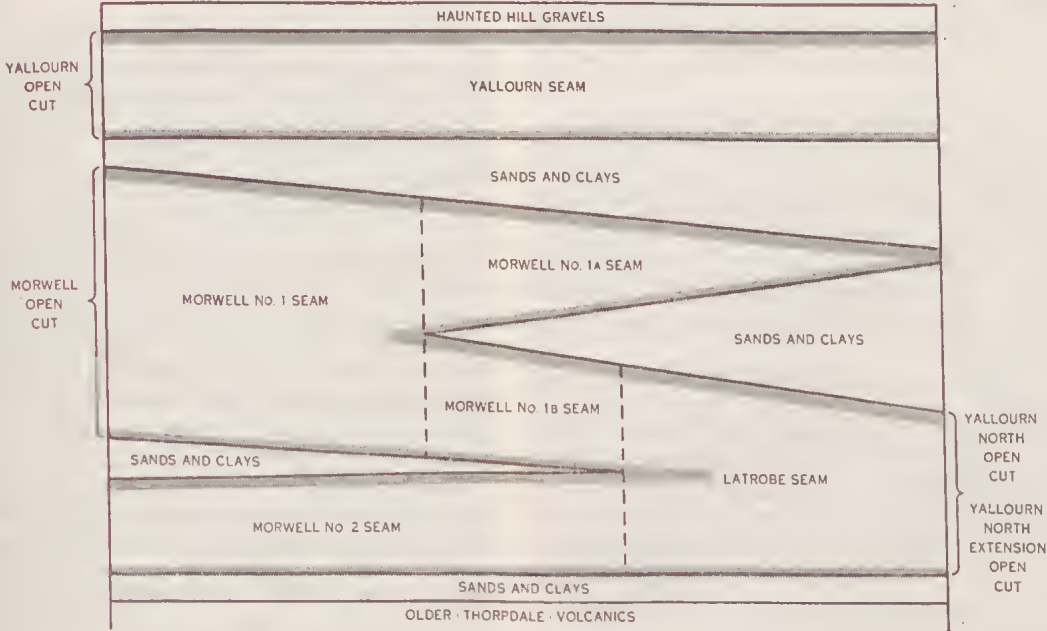


FIG. 2



DIAGRAMMATIC STRATIGRAPHIC COLUMN OF  
UPPER LATROBE VALLEY COAL MEASURES  
SHOWING THE COAL SEAMS BEING OPERATED  
IN THE VARIOUS OPEN CUTS

FIG. 3

ond is a large outcrop in the bed and along the northern bank of the Latrobe River adjacent to the entrance to the now abandoned Yallourn North Open Cut. It is likely that both outcrops had been observed and recognized over a hundred years ago as there are records of the latter having been shown to R. A. F. Murray of the Victorian Geological Survey in 1873. The coal was analysed by J. Cosmo Newbury in 1874.

In 1891, James Stirling who was Victorian Government Geologist, with remarkable foresight told a Royal Commission on coal that he believed the Latrobe Valley deposits to be the largest in the world. At that time only limited information could have been available to him. Apart from the open cut, originally known as the Great Morwell Brown Coal Mine but finally named the Yallourn North Open Cut, which had just been opened up, and several shallow pits or adits, Murray had records of only two bores, both deep, which had been drilled in the Latrobe Valley Depression and had penetrated brown coal seams. One of these, Maryvale No. 1, was drilled near Morwell township to a depth of 1,019 ft. Six separate layers or seams of brown coal, totalling 806 ft in thickness were intersected.

A brief history of the continued interest but spasmodic development of the brown coal deposits of the Latrobe Valley during the period up to the establishment of the State Electricity Commission of Victoria in 1919 was presented by Thomas and Baragwanath (1949).

#### YALLOURN OPEN CUT

The serious exploitation of the brown coal resources commenced at Yallourn in the early 1920s, with the construction by the State Electricity Commission of a power station of 75 MW capacity and a briquette factory (Chapman, 1967). A new open cut known as the Yallourn Open Cut was developed south of the Latrobe River and has been operated continuously ever since. (Fig. 2.)

In the area of this open cut the brown coal seam has an average thickness of about 200 ft with some 40 ft of soft sands and clays as overburden. Up to June 1969, the total quantity of coal won from this open cut was 282 million tons and the economic reserves remaining amount to some 450 million tons. At this time the open cut had reached a point some 3 miles south of the original opening-up point and the circumference of the cut was nearly 11 miles.

Additional power stations have been erected progressively at Yallourn and by 1963 the installed generating capacity had reached 642 MW. The original 'A' station of 75 MW was retired in 1968, and it is planned to place 'B' station, of

100 MW capacity, on cold reserve at the end of 1969 or in 1970. However, in the meantime, the construction of the 700 MW capacity Yallourn 'W' power station has commenced. This station will be completed by 1973 when the total installed generating capacity at Yallourn, based on coal won from the Yallourn Open Cut, will be 1,266 MW.

Over the period from 1925/26 to 1964/65 the annual production of brown coal from Yallourn Open Cut increased from 689,000 tons to 13,944,000 tons. In 1968/69 the production was 11,890,000 tons—the reduced quantity being more than made up for by the large increase in production from Morwell Open Cut over this period. A substantial proportion of the coal excavated at Yallourn is used for the manufacture of briquettes, and by 30th June, 1969, a total of 19,525,000 tons of briquettes had been produced by the Yallourn factories. This quantity represents more than 50,000,000 tons of raw coal.

As the retirement programme of the Yallourn Power Stations (B, C, D and E) has not yet been finally determined, the future rate at which coal will need to be excavated from Yallourn Open Cut is still indefinite. It is possible that annual production rates exceeding 18,000,000 tons may be necessary.

#### MORWELL OPEN CUT

Morwell Open Cut was developed to supply the coal to Morwell Power Station (170 MW), Morwell Briquette Factory and Hazelwood Power Station (ultimate capacity of 1,600 MW). Undesirable concentration of certain inorganic constituents in the coal from this open cut resulted in boiler fouling due to the formation of bonded deposits. For this reason briquetting coal for the Morwell factory was obtained from the Yallourn Open Cut, using the 90 cm gauge interconnecting railway. The boiler fouling did result in problems in the power stations burning the Morwell coal, but as a result of intensive investigations and redesign the availability of stations has been continually increased and is now regarded as satisfactory.

Coal winning at Morwell commenced in 1957, although some small tonnages had been dug in the development stages prior to that year. By 1968/69 the quantity of coal excavated from Morwell Open Cut had increased to 10,117,000 tons, bringing the total production since opening up to 55,982,000 tons. When Hazelwood Power Station is operating to its full capacity it is estimated that annual coal requirements from this open cut could reach 17,000,000 tons.

The Morwell Open Cut was opened up in the



Morwell No. 1 Coal Seam, and, when fully developed in depth, will have a permanent batter along its northern edge, made up of about 45 ft of sands and clays overlying some 450 ft of continuous, low ash-content, brown coal. A further coal seam, Morwell No. 2, occurs at greater depth, separated from the upper seam by 50-75 ft of sands and clays, and recovery of this deep coal may be economical at some future date. The sands contain waters under artesian pressure, and in fact the area forms part of one of the coastal artesian basins of Australia. In order to ensure stability of the operating faces and permanent batters, it has been necessary to progressively lower the artesian pressures in the vicinity of the open cut. This was achieved, initially by free-flowing bores and subsequently by pumping from large diameter bores installed progressively as the open cut was developed in depth.

#### YALLOURN NORTH OPEN CUTS

The Yallourn North Open Cut was handed over to the State Electricity Commission by the Department of Mines in 1924. The coal from this cut, the Latrobe Seam, is of lower moisture content and hence of higher net heat value than the Yallourn coal. It was used for local industry but a large quantity was railed to Melbourne for use by industry and in metropolitan power stations. The deposit at Yallourn North was not large (about 12,000,000 tons) and, when excavation ceased in 1956, a new open cut known as the Yallourn North Extension Open Cut, and located about three miles further east, was brought into production to maintain the supply of this same quality coal. In 1968/69 a total of 460,000 tons of coal was excavated, bringing the total Latrobe Seam coal won by the State Electricity Commission to 20,870,000 tons. Reserves at the Extension open cut are of the order of 30 million tons.

#### MINING AND TRANSPORT EQUIPMENT

At Yallourn Open Cut the overburden is dug by a bucket wheel dredger and is transported by conveyor into worked out areas in the open cut. The coal winning equipment consists of both bucket wheel and bucket chain dredgers. The largest of these, No. 8, is a bucket chain machine capable of digging 30,000 tons of coal per day. The coal is transported by a 90 cm gauge rail system to ditch bunkers serving the Yallourn Power Station and the briquette factories at Yallourn and Morwell.

A bucket wheel dredger also removes overburden at Morwell Open Cut. In the West Field a dredger, capable of digging 30,000 tons of coal per day, will excavate both overburden and coal; at that time the present overburden 90 cm rail

system will be replaced by belt conveyors. Both bucket-wheel and bucket-chain dredgers will operate on coal which will be transported to power station slot bunkers by belt conveyors.

At Yallourn North Extension Open Cut the overburden is removed by conventional earth moving equipment and the coal is won by power shovels. After crushing, the coal is moved by belt conveyors to bins, from which it is loaded into motor transport.

#### BROWN COAL RESOURCES

A systematic geological investigation of the coal resources of the Latrobe Valley Depression has been carried out over many years by the State Electricity Commission. This has involved an extensive programme of drilling, sampling and analysis. The structure and stratigraphy of the Coal Measures have been established (Thomas and Baragwanath 1949-1951), Gloe (1960, 1967), and the quality of the various seams determined in some detail (Urie, Garner and Holmes, 1968).

Thick coal seams occur close to the surface in two large areas known as the Yallourn-Morwell and the Loy Yang Fields, and also in several smaller areas. Existing open cuts and possible future developments are shown in Fig. 2. The split of the Yallourn-Morwell into the Yallourn-Maryvale and Morwell-Narraean Fields, as shown in this diagram, can be made on geological as well as on geographical grounds. It will be seen that, at this stage, the large Loy Yang Field remains undeveloped.

On a geological basis the coal reserves of the Latrobe Valley deposits have been calculated as 47,500 million tons proved, and 37,300 million tons inferred. Of the proved reserves some 29,000 million tons occur with less than 100 ft of overburden overlying the uppermost seam. Selecting the most favourable areas from which sufficient coal could be won by large scale open cut operations at about present day costs, and subject to other limiting factors such as townships, essential services, rivers, etc., readily minable reserves are estimated at approximately 10,000 million tons. Additional reserves could be won at higher cost, but the amount ultimately recovered will depend on the cost of alternative fuels, on the technological advances made in methods of coal winning and power generation, etc. (Chapman, 1967).

As stated above the economic reserves remaining under the present plan of operations for Yallourn Open Cut amount to some 450 million tons. The total coal reserves in this Yallourn-Maryvale Field that could be won economically from the Yallourn Open Cut and from new open-



ings further east amount to about 2,300 million tons.

The coal reserves for the designed Morwell Open Cut east of the Morwell River are approximately 600 million tons. A further 400 million tons could be won along the river valley by a western extension of the Morwell Open Cut after carrying out a diversion of the river. For the whole Morwell-Narracan Field total economic reserves are 2,200 million tons. This includes the coal from new openings in the Narracan area, west of the Morwell River.

It will be clear that the full development of the Yallourn-Morwell Fields requires the removal of most of Yallourn Township and a major diversion of the Morwell River (Urie, Garner and Holmes, 1968).

Proven deposits of winnable coal at Loy Yang are 3,400 million tons. An area which would probably be selected for initial development contains some 1,000 million tons of very low ash-content, good quality brown coal. The deposits are of the Morwell seams with coal thicknesses up to 400 ft and an average overburden thickness of 50 ft. The development of a field of these reserves would support about 3,500 MW of new base load generating plant over a life of 40 years.

#### LATROBE VALLEY ENERGY INDUSTRIES

(a) *Town Gas Manufacture:* In December 1956, the Gas and Fuel Corporation of Victoria commenced the manufacture of town gas from brown coal briquettes, using the Lurgi gasification process. The plant was established at Morwell and the gas transported to Melbourne by a high pressure, 18 in. diameter pipeline (Fig. 5). Since then about one third of the gas manufactured by the Corporation has been derived from this source.

With the introduction of natural gas to the Melbourne gas supply the operation of the Lurgi plant was gradually slowed down during 1969 and was finally closed down in November, 1969. At that time a total of 2,115,000 tons of briquettes had been converted to town gas.

(b) *Briquette Manufacture:* Brown coal is briquetted in order to produce a high grade solid fuel in convenient, hard lumps with a low moisture content. The briquettes have a moisture content of 15% and a calorific value of 9,600 Btu/lb—more than three times the heat value of in-situ Yallourn brown coal.

The total briquette production in 1968/69 was 1,471,600 tons of which 336,000 tons were produced at the Yallourn factories and the remainder at the newer Morwell factories. Since commencement of operations at Yallourn, 31,371,000 tons of briquettes have been manufactured.

As stated above, the use of briquettes for town gas manufacture has ceased, but an interesting prospect for a new briquette market is the manufacture of briquette char. This is a coke-like form of high grade carbon, in demand for metallurgical and chemical industries. A pilot plant, initially capable of producing some 30,000 tons of char annually, is being erected at Morwell and is expected to be in operation during 1970. To produce this quantity of char about 65,000 tons of briquettes would be required.

(c) *Electricity Generation and Transmission:* By 1969 the generating capacity installed in the Latrobe Valley made up 59% of the total capacity installed for the State, and in 1968/69 the output from the Latrobe Valley power station supplied 85% of the State's electricity requirements.

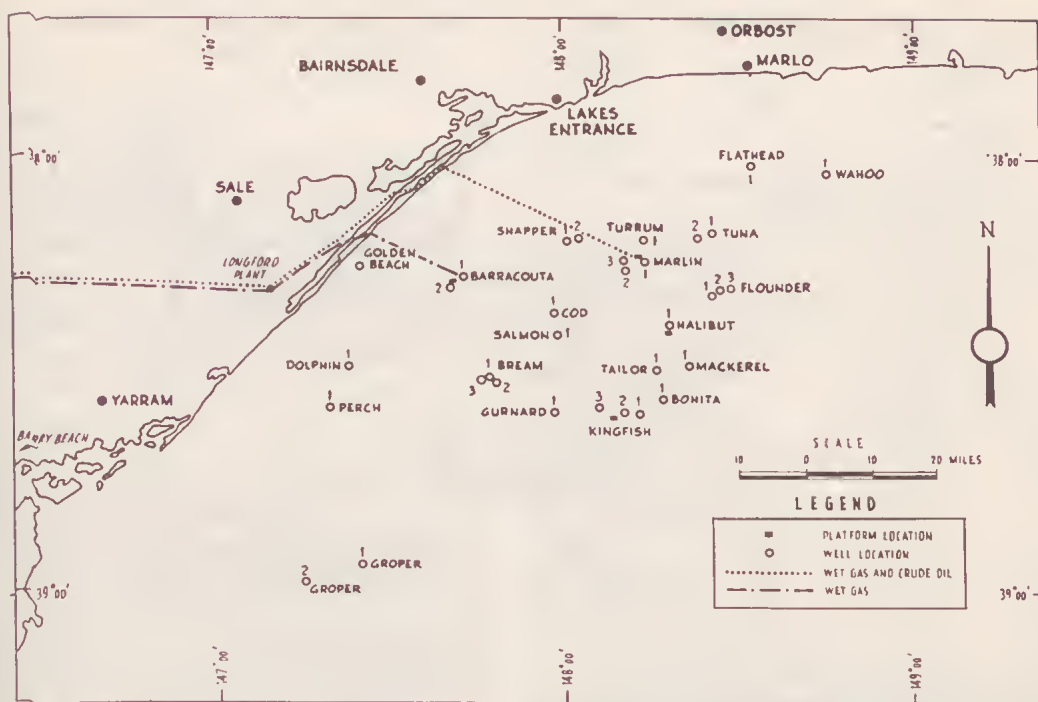
The continuously increasing power generation in the Latrobe Valley has been associated with development of transmission capacity of the circuits delivering power to Melbourne. The original 132 kV lines have been overlaid with 220 kV transmission and there are now three double circuit steel tower lines operating at this voltage over the 90 miles distance to Melbourne (Chapman, 1967). Lines to operate at 500 kV are now being constructed. One has been completed but is being operated at 220 kV. It will be converted to 500 kV in 1971 when the second line is completed (Fig. 5).

#### GELLIONDALE

The Gelliondale brown coal field (see Fig. 1) is located on the flat coastal plain between Gelliondale and Hedley and extending towards the coast. The bulk of the coal, with less than 100 ft of overburden, lies between the northern slope of a buried ridge of Mesozoic sediments and the low Mesozoic foothills to the north of Gelliondale. Coal at shallow depth has been proved for an area roughly seven miles long by one mile wide. The seam is about 250 ft in thickness but some boreholes to the south-east show thicknesses of up to 400 ft. The moisture content of this coal ranges between 60% and 70% and probably averages about 1% higher than Yallourn Open Cut coal. Ash contents are rather high and probably average more than 5% on a dry basis.

A small open cut was operated on this field in 1923. A plant for drying and briquetting the coal was installed, but worked only intermittently and was finally ceased.

Values calculated by the Victorian Department of Mines indicate total geological reserves of about 1,000 million tons. The main block of the coal is centred on the open cut and contains some 500 million tons. Economic mining reserves are likely to be considerably less.



GIPPSLAND BASIN - OIL &amp; GAS RESOURCES - LOCATION OF OFFSHORE WELLS

FIG. 4

### WONWRON

A small deposit of just over 2 million tons of good quality coal occurs about nine miles north of Yarram (see Fig. 1). The coal was first recorded in Middle Creek in 1876, where it was exposed in the creek bed. Although bores have shown the seam to reach a thickness of 220 ft, only thin splits occur in surrounding areas.

### THORPDALE-CHILDERS

Brown coal seams of the Childers Formation, and up to 20 feet thick, underlie flows of Older Basalt in the Thorpdale district, and have been known since before 1890. These deposits have been worked at a number of localities by means of adits. The coal was of good quality and was used by local industry. The biggest of these operations was at the Moolamoon Mine (see Fig. 1) where upwards of 58,000 tons was produced by bord and pillar mining methods. Operations ceased several years ago as the coal could not compete in price with that won by mechanized methods in the Latrobe Valley open cuts.

### OIL AND GAS

Minor shows of oil and gas have been obtained from several of the exploration wells drilled in the West Gippsland Region. These wells were

located along the Ninety Mile Beach. However, far more spectacular and successful results have been achieved from the offshore wells drilled by Esso Exploration Australia Inc. as part of their farm-out agreement with Hematite Petroleum Pty. Ltd. (Fig. 4). While the major oil and gas field discovered by them in the thick sands of the Latrobe Valley Coal Measures is not located within the West Gippsland Region, some of the development and exploitation of these new resources will take place within the boundaries of the Region adopted by this Symposium.

A brief summary of results obtained since the first bore was drilled in 1965 is set out below. Within Victorian waters a total of 30 exploratory wells have been completed and two are in progress.

**BARRACOUTA FIELD:** a gas field estimated to contain  $1\frac{1}{2}$  to 2 million million cu. ft of gas and 30 to 50 million barrels of condensate liquid. Oil has been discovered at a lower level and is to be developed for commercial production.

**MARLIN FIELD:** a gas field which has double the gas reserves indicated for Barracouta and is also somewhat richer in condensate. It contains some oil but reserves have not been assessed. No drilling has been carried out from the Marlin platform since a major blowout occurred in December

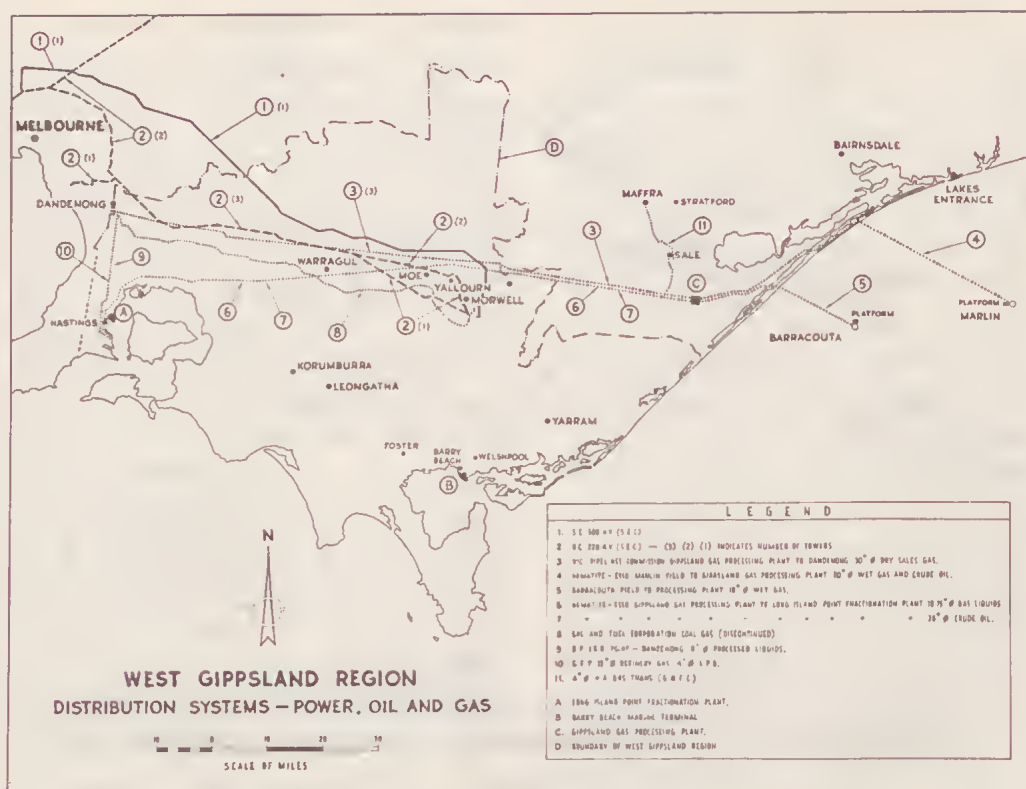


Fig. 5

1968, which was brought under control some four weeks later.

**KINGFISH FIELD:** an oil reservoir with reserves estimated at 1,060 million barrels. Two production platforms are being erected.

**HALIBUT FIELD:** an oil reservoir with reserves estimated at 440 million barrels. One production platform has been erected and development drilling is in progress.

**OTHER FIELDS:** drilling on the Tuna, Snapper and Flounder structures has indicated significant oil and gas occurrences which are currently being assessed.

Pipelines from Barraeouta and Marlin Platforms to the Longford gas processing plant and from there to Dandenong and the Long Island Point Fractionation Plant are shown (Fig. 4 and 5).

Golden Beach 1A well was drilled about 16 miles west of Esso's Barraeouta A1 well for an alliance of five oil companies including Woodside Oil Co. N.L., the original leaseholder. Gas was discovered on a structure somewhat smaller than the Barraeouta structure and its economic potential is still under study.

## PUMPED STORAGE HYDRO-ELECTRIC POTENTIAL

A preliminary investigation of undeveloped peak generating capacity from hydro-electric sources in Victoria has indicated that there are a number of potential pumped storage projects in the West Gippsland Region. One of the two most favoured in this area is on the Latrobe River and has a generating head of 1,150 ft. The other scheme is located on the Thomson River where an approximate head of 1,750 ft is available (Fig. 1).

## SUMMARY

One of the largest deposits of brown coal in the world provides the basis for the power and fuel complex which has been developed in the Latrobe Valley. Already about 85% of the State's electricity requirements are derived from this source, and ample reserves are available for future expansion.

As a result of the recent discoveries of large reserves of oil and gas in the offshore portion of the Gippsland Basin, important additions have been made to the State's indigenous fuel resources. These reserves are likely to be increased



as drilling continues and will have to be taken into account in future planning of power generation projects.

## ACKNOWLEDGMENTS

The author wishes to thank the State Electricity Commission of Victoria for its permission to present this paper. Much use has been made of papers written by other officers of the Commission, in particular, *The Latrobe Valley Power and Fuel Complex* by R. G. Chapman in 1967. The author also acknowledges data supplied by officers of the Victorian Mines Department regarding the black coal, and oil and gas resources.

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## APPENDIX 1

### FUEL AND POWER STATISTICS—LATROBE VALLEY

	1968/69	Total to Date
<i>Brown coal production—million tons</i>		
Yallourn North Open Cut	—	{ 20·87
Yallourn North Extension Open Cut	0·46	
Yallourn Open Cut	11·89	282·08
Morwell Open Cut	10·12	55·98
Total coal production	22·47	358·93
<i>Briquette Production—million tons</i>		
Yallourn Factories	0·34	19·52
Morwell Factories	1·13	11·85
Total briquette production	1·47	31·37
	1969	1974 (estimate)
<i>Installed Generating Capacity MW</i>		
Yallourn Power Station	566	566
Morwell Power Station	170	170
Hazelwood Power Station	1,200	1,600
Yallourn 'W' Power Station	—	700
Total installed capacity	1,936	3,036



# APPLICATIONS OF RADIOCARBON DATING IN VICTORIA, AUSTRALIA

Royal Society of Victoria Research Medal Lecture 1968

By EDMUND D. GILL\*

**ABSTRACT:** A brief outline of the radiocarbon method of dating is followed by a list of all the known datings of samples from Victoria. Literature references are given, but many datings are published for the first time. Illustrations are provided of how this form of dating has put perspective into geologic and archaeologic researches in Victoria. In conclusion, its value is assessed, and the need to distinguish varying purposes and degrees of reliability in dating are stressed.

## THE RADIOCARBON METHOD

As animals living on the floor of the sea are thereby protected from the direct effects of solar radiation, so we and all other living things on the surface of the earth are protected by the atmosphere from the direct effects of cosmic radiation. However, the upper atmosphere is so affected, and one result is the changing of nitrogen 14 into carbon 14 which is 15 per cent heavier than normal carbon 12. The transmutation of elements that was for so long denied as being impossible takes place continuously in this way.

Scientific methods are often devised, and then later the fundamental processes involved are elucidated, but the existence of radiocarbon was worked out theoretically by Professor W. F. Libby, who then made a search for it. Likewise its mode of origin was worked out theoretically and then established with the aid of high-flying balloons. Libby also deduced that the radiocarbon cycle of formation, of assimilation in all living things, and then decay back to nitrogen could be used as a timepiece for dating the past. The proliferation of radiocarbon dating laboratories from one in 1950 to over 80 in 1968 (many with multiple apparatus) is witness to the high value of this method for certain fields of scientific endeavour, as also is the considerable literature on the subject, and a special publication (*Radiocarbon*) for reporting results. It has dramatically brought into perspective the geologic, geomorphic, archaeologic and biologic history of the past 40,000 years.

When a radiocarbon atom changes back to nitrogen it emits an electron, and a radiocarbon

dating machine counts the flow of these electrons. The number per minute per gram of carbon allows the age to be calculated. The electrons punch a time clock, so to speak. Even in the richest material, the natural radiocarbon is remarkably scarce, having a concentration of only  $10^{-12}$ , so in ancient specimens the activity is extremely low. This low level counting is difficult and expensive. Minute amounts of contamination can spoil the count.

Having invented a new timepiece, Professor Libby had to calibrate it, and he did this by the radiocarbon dating of materials of known age. He used wood from an ancient Californian redwood (*Sequoia*), historically dated Egyptian wood, and such like (Libby 1955). There was sufficient correlation between the historic ages and the radiocarbon ages to indicate that a valuable tool for chronology had been discovered. Professor Libby's method was to reduce the sample to pure carbon, but later this was replaced by a gas (such as carbon dioxide) which provides (1) greater equality of opportunity for disintegrations to be recorded, and (2) the opportunity to alter the concentration of the disintegrations by increasing the pressure of the gas. The latter is an advantage where the sample is ancient and the disintegrations relatively fewer. Since the method was invented in 1950, many refinements have been made and corrections applied. Two major alterations of the natural level of radiocarbon have been discovered, viz:

- (1) That the Industrial Revolution resulted in vast quantities of dead carbon dioxide being poured into the atmosphere. This has diluted the concentration of  $^{14}\text{C}$ .

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- (2) That atom bombs have raised the level of  $^{14}\text{C}$  in the atmosphere so that the level is now 60 per cent greater than before they were exploded.

Air enriched in radiocarbon by an atom bomb can be traced, and so the speed of mixing of air measured. It takes only 5-10 years to spread through the earth's atmosphere. However, it takes thousands of years for complete mixing in the oceans. For example, Pacific waters decrease in  $^{14}\text{C}$  below 1000 m, and Antarctic waters upwelling from depth give an age of about 1800 years because they are deficient in radiocarbon (Rafter 1968). These deficiencies can be used for tracing the movements of bodies of oceanic water. Waters from two sites in the NE. Pacific Ocean at 2000 m gave dates of 2194 and 1480 y respectively (Williams et al. 1969).

Until recent years it was taken for granted that the rain of neutrons on the earth generating radiocarbon was constant, but it is now known that this is not so. Variations have been traced by counting tree rings back to 7100 years in redwoods and bristle cone pines (Ferguson 1968), then comparing the dendrologic age with the radiocarbon age (Damon et al. 1966, Dyck 1966, Jansen 1962, 1965, Kigoshi 1965, Suess 1967, Lerman et al. 1969, and others). Green (1968) queried my interpretation of radiocarbon dates from Aitape in New Guinea as a measure of the mean rate (he misquoted me as stating 'a sustained and constant rate') of tectonic uplift, but as the age is within the range checked by dendrologic chronology, there is insufficient reason for questioning the validity of the method. The effects of the sunspot cycle and geomagnetic variations are being studied (Libby 1965, 1967, Schell et al. 1965). The half-life of radiocarbon has not yet been finalized (Godwin 1962) so that a date  $\times 1.03$  is probably more correct. So there are many refinements needed, but Walton and Baxter (1968) consider that we are not yet at the stage where these can be satisfactorily applied.

There are other problems in radiocarbon dating (e.g. Shotton 1967). It has been found that plants growing in a lake which draws carbon from an ancient limestone in its floor can give dates of up to 2000 years, which is two millennia too old. Living plants growing at the sites of fumaroles, and of springs in ancient limestones, can give  $^{14}\text{C}$  dates up to 20,000 years too old. On the other hand, carbonates as in mollusc shells can be dissolved and reprecipitated using carbon dioxide from the atmosphere, so that the age is diluted, and the result is too young.

Enough has been stated here to give an indication of the nature and the measure of the prob-

lems in the radiocarbon dating method. It will be clear that one cannot take a sample, put it in a machine and obtain a reliable answer. How good then is the radiocarbon dating method? Have we overrated it? Dyck (1967) reviewed the method and stated, 'The radiocarbon cycle, like all natural phenomena, deviates from the ideal; but until more sophisticated dating methods are discovered, it will remain the best timepiece for the most recent past in spite of its imperfections.' He further commented that 'a value in error even by 10-20 per cent is better than a thousand intelligent guesses'.

Nevertheless, the method is being improved all the time. Originally, 1-2 pounds of sample was asked for, but now a date can be done (if necessary) on 5 g of carbon. The range of materials that can be dated has been considerably extended. For example, at first bone was considered unsuitable, but then it was found that a reliable date could be obtained from the organic fraction (essentially the collagen). However, this disappears in most places within 5000-6000 years. Now a method has been discovered for using the carbon from the bone apatite (Berger et al. 1964, Haynes 1968). Similarly the organic component of shell (conchiolin) as well as the carbonate can be dated. Sea water can be dated by extracting its carbon dioxide. Ice from ancient glaciers can be dated in the same way, but about a metric ton is required to produce enough carbon dioxide (Oeschager et al. 1967). Even iron can be dated by the small amount of carbon present (Van der Merwe and Stuiver 1968), and this has opened up new possibilities for dating Iron Age sites.

This introduction provides a very brief account of the existing status of the radiocarbon dating method in so far as it is relevant to the present purpose. The most important thing in this method is to know what is being dated, i.e. to understand the origin of the carbon that is assayed. Results from the dating of Victorian samples will now be listed, and then their meaning discussed.

## RADIOCARBON DATES ON SAMPLES FROM VICTORIA

All dates are B.P. (before 1950), and hereafter will be quoted in this paper by their list number. The date is followed by a brief description of the sample and note of its origin. If the collector's name is given, it follows in brackets; then the literature reference (if any) is provided. Some dates are published here for the first time. Some dates are different from those originally published because the laboratories concerned re-calculated them before publication in *Radiocarbon*. The differences are usually small.

1. **Modern (NZ-32).** Wood from central, most-decomposed part of root of standing *Eucalyptus oleosa* of 'Bull-mallee' habit about 4 ft in diameter, 40 ft high on Research Farm of Victorian Department of Agriculture (A. B. Costin). Grant-Taylor and Rafter 1963.
2. **170 ± 80 y (GaK-987).** Heartwood of large red gum, Victoria Valley, Grampians (L. K. M. Elmore).
3. **240 ± 84 (V-37).** Wood near base of soil profile in exposed bank of eroded creek on Kelleher property about 250 yd S. of Mt. Buller Rd. (A. Rundle). *Radiocarbon* 8: 510.
4. **260 ± 51 (ANU-30).** Charcoal from narrow vertical concentration (1 in. x 8 in.) in stream bed gravels beneath 78 in. of younger sediments of Campaspe prior stream exposed in gravel pit 6.5 miles NE. of Rochester (J. M. Bowler). *Radiocarbon* 10: 181. Date confirmed by N-294 225 ± 110 y.
5. **290 ± 50 (V-38).** Wood near base of soil profile in exposed bank of eroded creek on Graves property about 200 yd N. of Mt. Buller Rd. (A. Rundle). *Radiocarbon* 8: 509.
6. **370 ± 45 (NZ —).** Charcoal 6 ft from surface in centre of aboriginal rock shelter in dune limestone near mouth of Aire River. Mulvaney 1962.
7. **492 ± 36 (NZ —).** Fossil plant material (mostly reeds) from dark reddish-brown clayey zone 2 ft 6 in.—2 ft. 10 in. from surface, NE. corner of Lake Watt Watt, Snowy River Delta, Gippsland (E. D. Gill).
8. **538 ± 200 (C-601).** Charcoal from aboriginal midden in upper soil layer, Tower Hill Beach, between Warrnambool and Port Fairy. Libby 1955. Solid carbon method.
9. **760 ± 90 (GaK-965).** Shells of *Anadara trapezia* from slightly emerged shellbed on protected W. side of Point Henry, Corio Bay, Geelong (E. D. Gill).
10. **1020 ± 80 (GX-148).** Fossil wood from alluvium of Maribyrnong River at Braybrook exposed 2 ft from surface in a soil pit on E. side of Milleara Rd. and S. of Clarendon St. Gill 1966a.
11. **1177 ± 175 (C-600).** Charcoal from aboriginal midden at Goose Lagoon, W. of Port Fairy. Libby 1955; Gill 1955.
12. **1190 ± 90 (GaK-1059).** Organic fraction of aboriginal bones from Shire of Ararat gravel pit accompanied by mortar made from basalt. Gill 1969.
13. **1300 ± 250 (W-1478).** Fine carbonaceous matter from top of hardpan of soil in Port Campbell Project Square E5, 14.5–16.5 in. from surface. Gill 1965.
14. **1750 ± 115 (GX-60).** Marine shells from aboriginal midden in upper soil horizon, Tower Hill Beach, between Warrnambool and Port Fairy. Gill 1967a.
15. **1781 ± 115 (NZ —).** Carbonate from Green Gully human bones. Macintosh 1967, Mulvaney et al. 1970.
16. **1855 ± 85 (Y-150-1).** Charcoal from a second aboriginal midden at Goose Lagoon W. of Port Fairy. Gill 1955.
17. **1865 ± 85 (GX-149).** Small branch of red gum (*Eucalyptus camaldulensis*) of large tree exposed by the lowering of the level of Lake Bullenmerri, near Camperdown. The tree was in position of growth in a peaty soil (E. D. Gill).
18. **2370 ± 100 (GaK-2149).** Bore 1 through landward edge of sand barrier NE. of Seaspray, carbon of swamp deposit 8 ft 3 in. to 8 ft 7 in. Gill 1970b.
19. **2800 ± 100 (GaK-611).** Charcoal from aboriginal midden in the upper soil at Tower Hill beach. Gill 1967a.
20. **3010 ± 160 (W-125).** Charcoal from aboriginal fireplaces, Medway Golf Links, Braybrook, in wash with low dip overlying Doutta Galla Silt, revealed in soil pit section. Gill 1970a.
21. **3060 ± 100 (GaK-681).** Charcoal from aboriginal midden at excavation 5, site 9A, Yanakie, Wilsons Promontory. Coutts 1967.
22. **3145 ± 95 (V-78).** Charcoal on fire-burnt surface 8 ft beneath surface Maribyrnong Terrace near Green Gully, S. of Keilor. Bowler 1970.
23. **3480 ± 90 (GaK-970).** Charcoal from aboriginal midden in excavation 6, site 9A, Yanakie. Coutts 1967.
24. **3560 ± 100 (GaK-1060).** Marine shells 16–18 in. from surface in emerged stillwater marine deposit under Howe Flat, E. of Mallacoota Inlet, cf. 25 (E. D. Gill).
25. **3780 ± 100 (GaK-842).** Marine shells 28–36 in. from surface at Howe Flat, E. of Mallacoota Inlet, cf. 24 (E. D. Gill).
26. **3880 ± 250 (W-1477).** Resin of fossil grass-tree in situ from 10–11 in. below ground surface in Port Campbell Project Square R18, Port Campbell. Gill 1965.
27. **3920 ± 90 (GaK-968).** Aboriginal midden excavation 1, site 11, Yanakie. Coutts 1967.
28. **3980 ± 150 (GX58).** Marine shells 10–21 in. from surface and resting on marine aeolianite platform, SE. of Moulden's Quarry, Dennington. Gill 1967a; this date has also been published as 3750 ± 150 y.
29. **4100 ± 110 (GaK-2150).** Seaspray bore 1, organic carbon in sediment with vertical plant roots and freshwater sponge spicules, 11 ft to 11 ft 5 in. Gill 1970b.
30. **4170 ± 200 (GaK-1432).** Organic fraction of aboriginal bone from site 6, Keera Station, W. of Merbein (Chowilla Project, National Museum).
31. **4230 ± 65 (NZ).** Marine shells (*Katylesia peroni*) from emerged shellbed at Andersons Inlet. Gill 1966b.
32. **4315 ± 195 (GX59).** Marine shells from aboriginal midden in lower soil horizon at Tower Hill beach between Warrnambool and Port Fairy. Gill 1967a.
33. **4400 ± 220 (GaK-1433).** Organic fraction of aboriginal bones from site 6, Keera Station, W. of Merbein (Chowilla Project, National Museum).



34.  $4440 \pm 100$  (V-77). Fragment of *Eucalyptus camaldulensis* in MMBW trench 22 ft below surface, Maribyrnong Terrace near Green Gully. Bowler 1970.
35.  $4510 \pm 80$  (NZ). Marine shells (*Anadara trapezia*) from thin mud layer at top of sandy shellbed exposed in drain from Seaspray to Lake Reeve, Gippsland Lakes. Gill 1966b.
36.  $4550 \pm 120$  (GaK-2518). *Coxiella* shells in parna with fossil kangaroo, *Macropus (Megaleia) rufus*, at outlet of Lake Gnappurt to Lake Corangamite (H. E. Wilkinson).
37.  $4750 \pm 200$  (PIC-8). Marine shells (*Anadara trapezia*) from shellbed exposed in long drain running S. from Telegraph Road, Hedley, Gippsland, from 2.5-3 ft below surface. Parish of Welshpool, sect. 34 of B. Radiocarbon 7: 203; Gill 1966b.
38.  $4820 \pm 200$  (W-170). Wood of *Eucalyptus* bored by marine borers from marine shellbed 2.4 ft above LWM. on N. bank of Maribyrnong River at Brunel St., Essendon. Rubin & Suess 1955; Gill 1968a.
39.  $4830 \pm 250$  (W-1476). Charcoal 8-10 in. below surface and above australite in situ, Port Campbell Project Square H3, Port Campbell. Gill 1965.
40.  $4910 \pm 85$  (NZ). Marine shells from emerged shellbed at Foster Beach, Corner Inlet. Gill 1966b.
41.  $5120 \pm 120$  (GaK-610). Charcoal from aboriginal midden in lower soil horizon at Tower Hill Beach between Warrnambool and Port Fairy. Gill 1967a.
42.  $5350 \pm 90$  (GaK-1431). Organic fraction of aboriginal bones from site 6, Keera Station (Lybra Paddock), W. of Merbein (Chowilla Project, National Museum).
43.  $5350 \pm 350$  (W-1473). Charcoal 12-13 in. below surface and below level of australite in situ, Port Campbell Project Square L18, Port Campbell. Gill 1965.
44.  $5400 \pm 80$  (NZ-196). Wood from bore at pumping station on S. bank of Murray River at Psyche Bend, Mildura. Depth 35 ft from surface = 83 ft above sealevel (F. Penman, C.S.I.R.O., states drilling method ensures this depth correct for origin of sample). Ferguson and Rafter 1959.
45.  $5540 \pm 200$  (GaK-705). Organic fraction of aboriginal bones from carbonate zone at base of granitic talus apron overlying pediment 5 ft 6 in. from surface, Mitiamo. Gill 1967b.
46.  $5560 \pm 80$  (NZ—). Marine shells (*Katylesia rhytiphora*) from excavation for culvert, Miller's Road, Altona. Gill 1964.
47.  $5590 \pm 350$  (W-1474). Charcoal 10-11 in. below surface and above australite in situ, Port Campbell Project Square L19, Port Campbell. Gill 1965.
48.  $5620 \pm 90$  (NZ-279). Marine shells from emerged bed overlying freshwater Lara Limestone bored by marine molluscs, right bank Hovell Creek where crossed by Princes Highway N. of Geelong. Gill 1961.
49.  $5700 \pm 350$  (W-1475). Charcoal 11-12 in. below surface at level of australite in situ, Port Campbell Project Square L17, Port Campbell. Gill 1965.
50.  $5840 \pm 90$  (GaK 1429). Charcoal from among three aboriginal skeletons at site 1, Brown's Paddock, Keera Station, W. of Merbein (Chowilla Project, National Museum).
51.  $5850 \pm 320$  (PIC-9). Marine shells (*Homalina deltoidalis*) from excavation 26, Lake Pertobe, at foot of Cannon Hill, Warrnambool, from depth of 22 in. (Gill 1953, Radiocarbon 7: 203).
52.  $5900 \pm 550$  (GaK-1430). Aboriginal bones from site 5, Lybra Paddock, Keera Station, W. of Merbein (Chowilla Project, National Museum).
53.  $5990 \pm 105$  (V-75). Charcoal from lower part of the low terrace on right bank of Maribyrnong River near Green Gully tributary (J. M. Bowler).
54.  $6010 \pm 100$  (GaK-1100). *Eucalyptus* wood from 8 ft below surface in excavation in Power Street, S. Melb., associated with estuarine shells, and collected in 1900. Gill 1968a.
55.  $6010 \pm 110$  (GaK-971). Aboriginal midden on Cape Liptrap, Gippsland. Coutts 1967.
56.  $6140 \pm 150$  (GaK-2155a). Organic carbon from dark gray clayey silt, Bore 8, 9 ft 11 in. to 10 ft 8 in., Seaspray. Gill 1970b.
57.  $6230 \pm 430$  (PIC-7). Marine molluscs from depth of 4 ft in emerged shellbed covered by peat of swampy flat in research area of Department of Botany, University of Melbourne, near Tidal River, Wilsons Promontory. Gill 1967c; Radiocarbon 7: 203.
58.  $6235 \pm 120$  (GX150). Peat from Condah Swamp, 5-6 ft below surface, and near top of underlying basalt flow. Gill and Gibbons 1969.
59.  $6330 \pm 180$  (GaK-2154b). Marine shells in grey clayey silt from Bore 8, 8 ft to 8 ft 10 in., Seaspray. Gill 1970b.
60.  $6360 \pm 150$  (GaK-2154a). Same sample as 59 but date on marine shells. Gill 1970b.
61.  $6435 \pm 110$  (GX152). Carbonate from marsupial bones under parna dune on E. shore of Lake Weeranganuck 5 miles NE. of Camperdown (E. D. Gill, see 101).
62.  $6450 \pm 130$  (GaK-2153). Marine shells from Bore 1, 10 ft 10 in. to 12 ft 3 in., Seaspray. Gill 1970b.
63.  $6450 \pm 140$  (GaK-2155b). Marine shells from Bore 8, 9 ft 11 in. to 10 ft 8 in., Seaspray. Gill 1970b.
64.  $6460 \pm 190$  (NZ—). Bone collagen from fossil human remains, Green Gully, S. of Keilor. Macintosh 1967a, b; Mulvancy et al. 1970.
65.  $6500 \pm 200$  (PIC-10). Stratified marine shells (*Homalina deltoidalis*) from W. bank of Merri Canal, 1 chain downstream from Warrnambool Woollen Mill and near HWM., Warrnambool. Gill 1966b; Radiocarbon 7: 204.
66.  $6550 \pm 100$  (GaK-683). Charcoal from aboriginal occupation underlying GaK-681-2, excavation 5, site



- 9A, Yanakie, Wilsons Promontory. Coutts 1967; *Radiocarbon* 9: 56.
67.  $6605 \pm 190$  (GX151). Fragments of marsupial bones from Mcrri River, Bushfield, N. of Warrnambool. Gill 1967a.
68.  $6630 \pm 140$  (GaK-2152). Marine shells from Bore 1, 4 ft 8 in. to 5 ft 2 in., Seaspray. Gill 1970b.
69.  $6810 \pm 130$  (GaK-2151). Marine shells from Bore 1, 13 ft 10 in. to 14 ft 1 in., Seaspray. Gill 1970b.
70.  $7040 \pm 180$  (GaK-1061). Wood from emerged marine shellbed, Millers Road, Altona. Gill 1964.
71.  $7360 \pm 105$  (NZ). Chips of pedogenic calcite forming enrustation 1-2 mm thick on Keilor Cranium. Gill 1966a.
72.  $7380 \pm 250$  (W-1336). Humified fragments of stems (not roots) in top of carbonaceous hardpan on which australites are left following deflation. Site on old coastal road a short distance W. of entry road to Loch Ard Gorge. Gill 1965; *Radiocarbon* 7: 395.
73.  $7700 \pm 140$  (GaK-966). Charcoal from possible aboriginal fireplace in Doutta Galla Silt on N. bank of Maribyrnong River upstream from Green Gully (E. D. Gill).
74.  $7710 \pm 150$  (GaK-985). Charcoal from possible aboriginal fireplace, N. bank of Maribyrnong River in Doutta Galla Silt upstream from Green Gully, near 73 (E. D. Gill).
75.  $8155 \pm 130$  (V-63). Charcoal a few inches above Green Gully burial, near Keilor. Mulvaney et al. 1970.
76.  $8155 \pm 130$  (V-65). Charcoal from tree root burnt in situ c. 3 ft below Green Gully burial. Mulvaney et al. 1970.
77.  $8300 \pm 210$  (Y-151). *Eucalyptus* wood from stump in position of growth found 63 ft below LWM. at S. abutment of Spencer St. Bridge, Melbourne. Gill 1968a.
78.  $8330 \pm 190$  (GaK-1065). Peat of bog moss *Sphagnum cristatum* at level of *Eucalyptus* stump in position of growth (77) under S. abutment of Spencer St. Bridge, Melbourne. Gill 1968a.
79.  $8500 \pm 250$  (W-169). Charcoal from 2 ft. 6 in. above diastem in Doutta Galla Silt near bottom of quarry on S. bank of Maribyrnong River, Braybrook. Gill 1956.
80.  $8780 \pm 200$  (W-95). Another part of the fossil *Eucalyptus* stump listed number 77. Gill 1968a.
81.  $8990 \pm 150$  (V-64). Charcoal c. 4 ft below top of Green Gully burial, near Keilor. Mulvaney et al. 1970.
82.  $9340 \pm 200$  (Anon). *Eucalyptus* wood from bore testing foundations of new Art Gallery in S. Melbourne, from 93 ft below surface (= 64 ft below LWM.). Gill 1968a.
83.  $9650 \pm 100$  (GaK-1066). *Eucalyptus* wood from bore testing foundations for new Art Gallery, S. Melbourne. Gill 1968a.
84.  $11,030 \pm 140$  (V-74). Fragments of root charcoal from excavation at junction of Keilor and Intermediate Terraces on right bank, Maribyrnong River, near Green Gully (J. M. Bowler).
85.  $11,250 \pm 240$  (GaK-1062). Selected thick pieces of well preserved *Velesunio* shell from base of large aboriginal midden on right bank of Murray River, Redcliffs (H. F. Thomas).
86.  $12,810 \pm 210$  (GaK-1101). *Eucalyptus* wood from 93-94 ft in bore testing foundations of King St. Bridge, Melbourne. Gill 1968a.
87.  $12,900 \pm 210$  (GaK-742). Marine shells from E. Australian Continental Shelf at 70 fathoms (C. V. G. Phipps). Gill 1967c.
88.  $13,500 \pm 700$  (ANU-29). Charcoal from alluvial silt later buried by overbank deposition to depth 116 in. below present surface, exposed in left bank Goulburn River 9.5 miles ENE. of Echuca (J. M. Bowler). *Radiocarbon* 10: 181.
89.  $13,700 \pm 250$  (Y-170). Braekish water gastropod shells (*Coxiella*) from marsupial bone bed on E. side of Lake Colongulac, near Camperdown. Gill 1963; Barcndsen, Decevey, and Gralenski 1957.
90.  $14,600 \pm 200$  (GaK-1064). Carbon from podsolic hardpan 2 ft 6 in. from surface thereof where pan 5 ft thick in road cutting at top of hill W. of Sherbrook River on Ocean Road, E. of Port Campbell. Gill 1970c.
91.  $14,940 \pm 500$  (V-79). Wood charcoal from section through Keilor Terrace exposed on right bank of Maribyrnong River upstream from junction with Green Gully, near Keilor (J. M. Bowler).
92.  $15,000 \pm 1500$  (NZ-366). Small sample of charcoal in Keilor Cranium Quarry from about the level from which the cranium came. Because sample so small, carbonate not removed.
93.  $15,200 \pm 320$  (GaK-509). Bones from stratified layer, McEacherns Cave, 5 miles N. of Nelson. Wakefield 1967.
94.  $17,300 \pm 300$  (V-73). Charcoal from extensive surface with oxidized silts, Green Gully excavations (J. M. Bowler). Mulvaney et al. 1970.
95.  $17,800 \pm 600$  (GaK-2516). Charcoal from near base Doutta Galla Silt, Keilor Cranium site, Gallus sample KA395.
96.  $18000 \pm 500$  (NZ-207). Charcoal from aboriginal fireplace 5 ft 9 in. below level of cranium from Keilor Cranium Quarry in Doutta Galla Silt where Dry Creek enters Maribyrnong River. Gill 1967a.
97.  $19,300 \pm 600$  (GaK-2517). Wood from gravel with marsupial bones under 112 ft of basalt, Ettrick Bore 3 (Geological Survey of Victoria).
98.  $20,100 \pm 500$  (NZ —). Earthy charcoal near beach level in gray parna with reddish soil (interpreted as burnt ground) immediately underneath, the structure dipping lakewards at 30°, SE. shore Lake Colongulac near Camperdown (E. D. Gill).

99.  $22,850 \pm 750$  (GaK-1067). Marine shells from emerged shellbed under peat, Goose Lagoon, W. of Port Fairy (E. D. Gill).

100.  $24,000 \pm 3,300/5,700$  (ANU-81). Charcoal from Gallus excavation at Keilor Cranium site, about 40 in. from ANU-65. *Radiocarbon* 10: 189.

101.  $25,300 \pm 1,200$  (GaK-986). Brackish water gastropod shells (*Coxiella*) from bone bed below parna dune at Lake Weeranganuck (E. D. Gill, see 61).

102.  $28,240 \pm 1,100$  (Y-230). Brackish water shells (*Coxiella*) from parna dune on E. shore of Lake Corangamite near Candare, Beeac, Military map 628, 956. Barendsen, Deevey and Grolenski 1957.

103.  $>30,000$  (W-185). Marine shells from deposit of Port Fairy Calcarene on emerged shore platform at Two Mile Bay W. of Port Campbell. Baker and Gill 1957.

104.  $30,700 \pm 1,850$  (V-76). Charcoal fragments from MMBW trench across Maribyrnong River near Keilor, from W. bank in soil developed in material of Arundel Terrace (J. M. Bowler).

105.  $>31,000$  (V-23). Wood of *Eucalyptus camaldulensis*, Murmungee 38, Ovens Valley (B. R. Thompson). *Radiocarbon* 8: 509.

106.  $31,600 \pm 1,100/1,300$  (ANU-65). Charcoal from third of four strata about 40 in. beneath face of Keilor Terrace in Gallus excavation, Dry Creek, Arundel. *Radiocarbon* 10: 189.

107.  $>35,000$  (W-195). Marine shells from Port Fairy Calcarene (Gill 1956). Dated 120,000 years by Valentine, using ionium method.

108.  $>41,000$  (GaK-2045). Wood from Moray St. Gravels in foundations (pier 15) of Lower Yarra Crossing (A. E. Makram, Victorian Mines Dept.).

109.  $41,700 \pm 1,900$  (GaK-890). Humified wood from sand 158-192 ft in. bore 11.5 miles S. of Benetook, NW. Victoria (F. N. Bethune).

## INTERPRETATION OF RADIOCARBON DATES

With the half life of radiocarbon still not finalized, and with a number of corrections still to be applied, the accuracy of radiocarbon dating is not that which is suggested by the form in which it is expressed. Dates often conclude in numbers less than ten, so that the figures have the appearance of an accuracy they do not possess. To express the figures as dates AD or BC likewise gives the impression of an accuracy which does not apply. On the other hand, radiocarbon dates fix time with an accuracy which has not hitherto been possible. An outstanding advantage is that they come from a different discipline, and so act as a check on deductions from the earth sciences. There is no easy way or comfortable short cut to dating the past. All the evidence available needs to be brought together and the results checked

inductively. The ideal is a self-checking network of dates determined on the most reliable materials such as wood or charcoal. Samples for such a network are seldom available, and even when they are, the cost is often too high. In all radiocarbon dating the geochronologist should consider (a) what in fact he has dated, and (b) what is the order of accuracy attained.

A radiocarbon assay sometimes raises a problem instead of solving one. Thus an assay of charcoal from a camp site of the extinct Tasmanian Aborigines gave a date in the future, which is obviously incorrect. Another example is the effort to age the sediments in Lake Eyre in Central Australia. In preparing a report for INQUA on the Holocene of Australia, the literature on Lake Eyre was studied. King (1956) showed that a freshwater limestone underlay the area, and that over this was a series of layers which indicated, in general, an increase in salinity. His geological section of Sulphur Peninsula showed a bed of sulphur nodules 26-27 ft 6 in. from the top of this horizontal series of layers. The nodules included organic matter that gave a radiocarbonage of  $19,200 \pm 500$  years. Apart from some windblown sand, the top bed in the section is one rich in the shells of *Coxiella*, which grows in brackish lake waters. Since this bed was emplaced, it appeared, the present basin of Lake Eyre had been scooped out, leaving cliffs of former lake sediments now standing 36 ft above the present lake floor. As the lake floor is below sealevel, the only means of erosion appears to be the wind. The question arose as to whether in a drier postglacial period, the area had dried up, the lake floor was desiccated, and the present basin eroded. If this were so, the shellbed would provide a maximal date for this important event. With the co-operation of Mr. R. C. Sprigg, a large sample of the shells was obtained. A part was analysed by the Chief Government Chemist in Melbourne, and a part sent for radiocarbon assay to Dr. Athol Rafter in New Zealand where the sulphur nodules had been dated. The analysis revealed the following percentages—calcium 13.3, carbonate 12.5, sulphate 11.9, silica 54.4—so the calcium carbonate constituted about 20.8 per cent of the sample and gypsum 16.8 per cent. Since the shellbed apparently superposed the nodule bed, a date considerably less than 19,000 years was expected, but the date obtained was  $39,200 \pm 1300$  years. Thus the age obtained was of a magnitude of about 6 times greater than was expected, i.e. too old to be explicable by contamination. As a check, another part of the same sample was sent to New Zealand for radiocarbon dating, and this gave an age of  $32,200 \pm 1450$



years. This comparable age showed that the bed was definitely older instead of younger than the bed with the sulphur nodules.

Johns (1962) re-studied Lake Eyre geologically, and suggested two possible solutions of this problem raised by the radiocarbon date for the shells (the second date had not been obtained then), viz:

- (1) Superposition does not apply. The sulphur nodule bed may be alongside instead of stratigraphically below the shellbed.
- (2) The sulphur nodules used for dating were taken from the lake floor where they had suffered aerial contamination.

Point (1) is important, and can be checked by boring. Point (2) provides an inadequate explanation because the material used for dating was the biologic carbon of recently living species, so contamination of this order is very unlikely.

I offer for investigation a third possibility:

- (3) The greater age of the shellbed could be due to shells being excavated from the lake floor and blown up on to the peninsula during a dry period. The age obtained would then be the age of the material and not the age of its emplacement.

Sedimentary structures in the bed could probably prove how it was emplaced, and its relationship to the bed below reveal whether it is part of an uninterrupted sedimentary sequence. Subsequent filling of the lake could cause cliff cutting with removal of the ramp up which the shellbed material blew, and thus the formation of the present cliffs. The appreciable difference in age obtained by radiocarbon assay for the shells (32,200 and 39,200) could be explained if the material is a mixture of shells removed from the floor of the lake. A radiocarbon dating of material from the bed below the shell layer would also assist elucidation of the chronology.

So the attempt to date the Lake Eyre sediments did not provide an answer but only a new problem. However, this is itself helpful, and in due course the problem will be solved.

## INTERPRETATION OF VICTORIAN RADIOCARBON DATES

The two samples (8, 11) sent to Professor W. F. Libby were the first specimens from Australia to be dated by this new method. Since then there has been a progressive interpretation of those results, both because of greater knowledge of the radiocarbon method, and because of growing knowledge of the environment from which the samples came. So it is with all radiocarbon dates. There is a growing appreciation of what a dating

means and what can justifiably be read from it. For many years no funds were available locally for radiocarbon dating, and those done were by the kindness of the laboratories, or in exchange for services. Thus for a long time only spot dates here and there could be assayed, but they were nevertheless very helpful in giving some idea of age. As adequate resources for full radiocarbon dating are still not available, it will be some time before we can say that any event or process has been adequately dated. Thus the applications of dating which will now be outlined should be considered as in the nature of first approximations. However, the differing purposes of radiocarbon dating should be recognized: for example, the purpose of the geologist carrying out a reconnaissance survey and wanting some idea of age would differ from that of an archaeologist working inch by inch through a cave deposit and seeking refined dating.

## RADIOCARBON AND ABORIGINAL ANTIQUITY

The discovery of the Keilor Cranium in 1940 (Mahony 1943a, b) stimulated the study of the Maribyrnong River Valley. Keble and Macpherson (1946) gave a thalassostatic interpretation of the fluvial terraces of the Maribyrnong River Valley, and on this basis dated the Keilor floodplain as Würm 1. When the writer succeeded Keble at the National Museum, Keble strongly recommended that the study of the Maribyrnong River Valley and the Keilor Cranium be continued, and so this was done. However, a different interpretation of the terraces was reached because they were regarded as fluvial in origin. The terrace of yellow silt that contained the Keilor Cranium was traced down the valley and these compacted oxidised sediments were seen to descend below sealevel and to be covered by the unoxidised uncompact sediments of the Flandrian Transgression (Gill 1962). The terrace was thus graded to a lower sealevel, earlier than the Postglacial sediments. It was therefore dated as Late Glacial. This is about as far as one could go without isotopic dating. The formation characterized by yellow silt (in which the Keilor Cranium was found) is the Doutta Galla Silt, and its surface is the Keilor Terrace (Gill 1962). The upper part of the terrace is an unusual sediment. It is fine grained and exceptionally well sorted, so much so that overseas visitors usually take it for loess. The quartz grains are of the size carried by the winds, and it is considered that this was a windblown deposit later washed into the river valley, because it has sedimentary structures and it does not extend up the valley walls. A few de-



posits of this kind have been found in hollows in the basalt plain above the valley. It is this fine grained material that has been worked commercially for non-ferrous castings. In such a quarry the Keilor Cranium was found, and this explains why the quarry was no deeper than it was. Any sediment from below the level of the floor of the quarry was rejected by the foundries. Samples so far dated from this upper part of the terrace range from 6460 to 8990 years. The top of the terrace has not yet been dated, but it is older than 4400 years. A sample from the level of the Cranium dated 15,000 years, but was too small for precise dating. However, it gives the order of age, which is the maximal radiocarbon date for human skeletal material found in Victoria up to the present, although some may well be older. The relatively poorly sorted sediments below this level, often current bedded, date up to 18,000 years (95, 96), which must be near the maximal date of the deposit. Sample 95 dated 17,800 years came from only 5 in. above the basal gravel. A midden of similar age ( $18,200 \pm 800$ , GaK-2514) has been found at Lake Victoria in NSW, not far from the Victorian border. From the bottom of this terrace have come the oldest dated Aboriginal implements, universally accepted as such, at Keilor. Bones, scattered charcoal and chipped stones excavated by Dr. A. Gallus and members of the Archaeological Society of Victoria are dated as 24,000 and 31,600 years. The detailed evidence of these ancient sites is awaited with interest. The writer interprets the matrix as slumped material from the Arundel Formation. It contains extinct giant marsupials while only extant species are known from the Dousta Galla Silt. Similar material at the Green Gully site was dated 30,700 years. Thus in the Maribyrnong River Valley radiocarbon has given much more precision to dating, and has made possible correlation from one part to another.

The radiocarbon dating of carbonate encrustation from the Keilor Cranium illustrates the problem of knowing what exactly has been dated. Chips 1-2 mm thick from the skull gave an age of 7360 years. What does this date? X-ray determination at the Institute of Nuclear Sciences in New Zealand showed the material to be calcite, the more stable form of calcium carbonate. On the other hand, the mineral deposit was thin, and chalky on the outside. Some exchange with soil air since it was deposited is likely. The date is minimal for the Cranium, but how far from the real date? The Cranium came from the B-horizon of a paleosol, and so the carbonate was derived from the leaching of the ground above. As the soil profile dried out, the carbonate was deposited,

utilizing the air in the soil. Thus after the Keilor Cranium was deposited by the river, at least two ft of sediment were deposited above it, and a soil profile gradually developed therein, so reducing its thickness. By analogy, it is estimated that this would take at least 2000 years. The Cranium is therefore older than 7360 years by the time taken to deposit 2+ ft of sediment, by the time taken to develop the soil profile (so depositing the carbonate), and by the amount of age dilution that has occurred since. Thus the  $^{14}\text{C}$  date is the age of the soil air used to precipitate the carbonate plus any age dilution that has occurred in the meantime.

By contrast we may consider a site where the geology is not known, e.g. an extensive aboriginal midden at Redcliffs on the Murray River (85). Mr. H. F. Thomas of Mildura and his associates found this midden and asked for advice about dating it. Some thought it to be historically recent, but there was reason for believing it to be older because of its compaction, and its relationship to the erosion of the high river cliffs upon which it stands. The radiocarbon date was determined on mussel shell (*Velesunio ambiguus*) which was thick and well preserved, and from which the outer surface had been stripped. However, the date of 11,250 years was a surprise. There is no reason to doubt this date for the base of the midden, and indeed it could be younger than the real age in that the material assayed is carbonate. Other middens in the region have since been dated as  $15,300 \pm 500$  (GaK-2515) and  $18,200 \pm 800$  (GaK-2514) y BP.

Control on radiocarbon datings on freshwater mussel shells (*Velesunio ambiguus*) consists of four of the following assays:

1. Shells with soft parts collected in 1934 (before atom-bomb contamination) by Messrs E. L. G. Troughton and H. O. Fletcher on Avon Downs Station, Queensland, gave a date of  $-8.3 \pm 1$  years (DSIR Institute of Nuclear Sciences, NZ) which Dr. T. A. Rafter states 'is a very good zero for pre-bomb fresh water mussels. Its  $^{14}\text{C}$  activity corresponds almost exactly to the  $^{14}\text{C}$  activity of the atmosphere here in 1934 due to the Industrial Effect depletion since 1890'.
2. Shells collected near Tartanga on the River Murray in S. Australia by Dr. N. B. Tindale in 1953 gave a date of  $-39 \pm 14$  years (Broecker and Olson 1959, p. 128).
3. Shells collected by me in Dalrymple Creek near the Talgai Cranium site on the Darling Downs, Queensland in 1963 have suffered contamination (presumably from atom bombs) and gave a future date, viz.  $-850 \pm 170$ , GX-62).

As yet we know little of the prehistory of Vic

toria. Radioecarbon datings have been obtained for cultural objects, but these are unlikely to be the earliest occurrences. Nevertheless, the few dates obtained have already helped perspective in our prehistory.

## RADIOCARBON AND THE LONGEVITY OF NATIVE TREES

In 1895, people passing over the Black Spur to Healesville in the daily Cobb and Co. coaches saw 'Uncle Sam', a giant *Eucalyptus* over 250 ft high (measured by theodolite) given variously as 36 ft and 40 ft in diameter 6 ft from the ground (Caire 1905). One and a half miles away they could see the stump of 'Big Ben' felled for the Paris Exhibition and measuring over 250 ft high with a circumference of 57 ft. After it was felled, the rings were counted and found to be 1200 in number. The 'Necrim Giant' was measured by the Government Surveyor as 325 ft high and 48 ft in circumference. Many of these great trees were killed by the 1902 bushfires and other fires later. Many have been felled. Few people nowadays have seen such trees. How old were these trees, and to what age do our native trees grow? It has been claimed that the red gum (*Eucalyptus camaldulensis*) grows to over 1000 years old. A similar claim has been made for the grasstree (*Xanthorrhoea australis*) and the bull-mallee (*Eucalyptus oleosa*). Radiocarbon dating can provide some real information on this subject. A botanist chose from the huge lignotuber of a big bull-mallee a sample which it was thought would indicate the age of this tree, but the wood gave a modern date. One has often been pressed to make a radiocarbon assay of grasstrees, but when one notes how quickly they regenerate after a bushfire, and that the specimens planted by Guilfoyle in the Royal Botanic Gardens between 1870 and 1880 are now 10 to 15 ft high, it would not appear that they have a great antiquity. So far the funds have not been available for testing grasstrees, but radiocarbon could provide an answer. The Southern Beech (*Nothofagus*) in New Guinea was dated on heartwood at  $550 \pm 85$  years. The heartwood of a red gum (*E. camaldulensis*) from the SE. of S. Australia gave a qualitative date of 950 years. The laboratory concerned made a rapid test and not a definitive assay, but the order of age is of great interest. Having asked Mr. L. K. M. Elmore of Hamilton to watch for any particularly large red gum being felled in his district so that the heartwood could be dated by radiocarbon, he obtained such a sample from what appeared to be a very old tree. It was growing within 30 ft of the vertical banks of Dwyers Creek, which revealed 8 ft of sandy silt overlying

ferruginous clay. At ground level the tree had a circumference of 53 ft 6 in., at 4 ft from the ground a circumference of 40 ft, at 14 ft from the ground 27 ft, and the sample was taken from the apex of the hollow inside the tree at about 16 ft above the ground. The rings of *Eucalyptus* are not laid down regularly and so cannot be used for determining the age of a tree, so it was hoped that the present sample would date the antiquity of this big red gum. It was collected in 1962 from the property of Mr. D. McArthur in the Victoria Valley in the Grampians. The age obtained was  $170 \pm 80$  years, which was less than expected. The matter was submitted to Dr. M. R. Jacobs, Director-General of the Commonwealth Forestry and Timber Bureau, who stated that 'the wood of all hardwood trees matures from the cambium in quite strong tangential compression and severe longitudinal tension. In the case under discussion tangential compression would be the important factor although the longitudinal tension can crush the interior cells and make them more susceptible to attack by fungi'. He stated that as the tree is narrow above the spread hollow part of the trunk, the date appears to be quite reasonable. He provided a photograph of a red gum planted E. of the Andes in Argentina and quoted as 30 years old, but a large tree of the order of five feet in diameter. The tree could not be much older than 60 years. So it is possible for red gum trees to grow very rapidly. Thus the red gum in the Victoria Valley appeared to be a very old tree but it was only of the order of 170 years old. The centre had failed and the tree had expanded to give the appearance of a tree of great antiquity. The samples of *Eucalyptus camaldulensis* were determined by Mr. H. D. Ingle of CSIRO Division of Forest Products.

Thus very little has been done to test by the effective radiocarbon dating method the longevity of our native trees. This question has interest for the geologist because on dating a piece of wood from a geologic formation he wishes to know the biologic age of the sample he has dated, and what is the maximal age for the species concerned. For example, when the foundations of the new Art Gallery beside St. Kilda Road in Melbourne were being tested, wood was obtained at 94 ft from the surface in one of the bore holes. The site is that of an ancient course of the River Yarra, and the level from which the wood came was 64 ft below sea level. The age obtained was  $9340 \pm 200$  years. Is this approximately the age of the sediment at that level, or is this a piece of wood of a 1000 year old tree? Judging by dates obtained for other levels in the delta, the tree is probably not so old. However, this indicates the



type of problem which can arise, i.e. the biologic age of a piece of wood dated from a geologic formation.

## RADIOCARBON AND THE AGE OF AUSTRALITES

At the request of the National Aeronautics and Space Administration, and with financial assistance from them, australites were sought in situ for dating. When did our planet sweep up this shower of glassy tektites from space? With the help of a group of university students, an archaeological type of excavation was dug at Port Campbell and 14 australites discovered in place. The site revealed 10-12 in. of sandy topsoil, under which was a hardpan consisting of sand cemented with humic matter and iron. Although this appeared to be a normal soil profile, it was discovered that the lowest 2-3 in. of the topsoil contained an increased percentage of heavy minerals, the australites, aboriginal artifacts, some buckshot gravel, and charcoal. Winnowing concentrated these materials at this level, and later the topsoil was reconstituted. This in itself was a useful discovery. When did it occur? Humified pieces of plant stem (not roots) in the top of the hardpan dated 7380 years. Samples of charcoal in the lowest 2-3 in. of the topsoil gave dates from 4830 to 5700 years. Just above this level, in the sand of the reconstituted topsoil, a ring of grasstree resin gave a date of 3880 years. Thus between 4000 and 6000 years ago this topsoil was winnowed during a time of greater soil instability. There is widespread evidence of a small climatic change at this time, including the evidence of marine fossils. In this same area a place was found where the hardpan was exceptionally thick, and in the middle of it (2 ft 6 in. from the top of the hardpan) a sample was obtained that gave a date of 14,600 years. The relationship of this hardpan to present sea level, and the fact that it runs down the walls of quite young valleys, shows that it is fairly recent geologically. It belongs to the cooler and presumably wetter conditions of the Last Glacial. Radiocarbon has thus dated the time of emplacement of the australites where they were discovered, but how is this related to the time of fall? In this situation, the hardpan appears to provide a maximal date for the australites, but if the buckshot was washed in from some other site, perhaps the australites were also washed in. Thus a search is being made for any older formation from which they could come.

## RADIOCARBON AND CLIMATIC CHANGE

Because of the considerable range of weather in a single day, the considerable climatic change

over the yearly seasonal cycle, and the larger cycles of drier and wetter years, all enveloped in the bigger cycles of major climatic change, it is difficult to trace with assurance the climatic changes of the past. The gross change of climate between the mid-Tertiary and now is obvious. In the shorter range of Quaternary time there have been changes, but they are not so apparent. Because the investigation is difficult, some abandon it. Some will accept only that minimal amount of change that can be fully proved, but this is not the product of a balanced judgement. By considering patterns of change over wide areas of country, the small local changes can be smoothed out, and the general direction of change discerned. We plot change against time, and isotopic dating is the best way to determine the time factor. As examples, let us consider three types of regional pattern that have changed with time.

1. SOILS: The terrain has experienced successive periods of stability and instability as Butler, Churchward, Walker, Galloway, Bowler and others have described. Changes in regional sub-aerial conditions have brought about these and other changes in the nature of the landscape. Thus the terrain is covered by a patchwork of soils not due simply to differing substrates and differing degrees of development (cf. Gibbons and Gill 1964). As a starting point let us note that in the Pliocene lateritic soils were developed in both N. and S. Victoria. This was before the main uplift of the Dividing Range during the Kosciusko Epoch. The formation of laterite depends on alternate wet and dry seasons as in a monsoon area. To have laterites develop over both N. and S. Victoria proves that the climatic conditions were different from the present. However much time were allowed, laterites could not be formed under present conditions, which are not such that the soil could be leached to the depth, and with the severity, that occurs in lateritisation. Conversely, would it not be a surprising thing if the uplift of the Dividing Range caused no difference in climate? Subsequent to the laterites in S. Victoria krasnozems and red earths were formed, followed by podzolic types. In N. Victoria the laterite was followed by a soil in which silicified sandstone, silcrete, or common opal was formed. This was followed by a series of carbonate-bearing soils with intercalated periods of soil destruction. That the soils mobilised iron, then mobilised silica, and later carbonate, indicates changes in climatic conditions. The amount of rainfall, the degree of leaching, and the geochemical conditions are different for each of these types of soil. The geologic and pedologic evidence indicates that there were at least three



cycles of earbonate soil formation. Radioearbon shows that one is late Pleistoeene to Holoeeene, one is Last Glacial, and one is beyond the time range of the method.

2. DUNE SYSTEMS: In N. Victoria and the adjacent parts of New South Wales and South Australia there is a very extensive system of E-W. dunes. During the 1945 and recent droughts, terrain instability increased (with development of dust storms) and the crests of some of the dunes began to move. Nevertheless, as a system, these dunes are dead. Palsosols within them show that there were stages in their construction, i.e. oscillations of climate. An auger hole was sunk through one of these dunes on Berribee Station in the extreme NW. of Victoria. In addition to the earbonate horizon of the present soil at the surface there were two other earbonate horizons. The bore traversed more earbonate-impregnated sediment than earbonate-free sediment. So much earbonate could not be produced from the sediments themselves and so must have been blown in, presuming dust storms. The dating by radiocarbon of the palsosols in this dune system is now being attempted. This system is built over the Last Glacial terrain, and radiocarbon is our only means at present of dating the climatic changes that brought about these geomorphic changes.

3. SEALEVELS: Quaternary changes of sealevel are associated with changes in climate. These will be discussed in a separate section.

## RADIOCARBON AND SEALEVELS

One of the surprising results of modern science is that sealevel is so mobile. It is only about 7000 years since Port Phillip Bay and all the harbours of Victoria were mostly dry land. Radiocarbon dating has contributed in a major way to the study of sealevels. Emerged marine beds of Holoeeene age have long been observed in Victoria, but their dating was generalized, correlation from place to place was hazardous, and international correlation impossible. Usually the more recent a process, the more accurately it can be traced, and the more fully understood, but with sealevels it is not so. The changes over the past 11,000 years are the subject of symposia in various parts of the world, and there is major disagreement as to what happened. For instance, some believe there was a stand or stands of the sea up to 10 ft higher than now in the last 6000 years, while others deny this. It may well be that there is some factor involved not recognized before, or inadequately assessed. However, if in each area of the world the evidence is recorded and dated by radioearbon, then it will be possible to think more objectively on this matter. Insufficient data

and too few dates are the present limiting factors.

The coast of Victoria is essentially E.-W., and extends for 500 miles of latitude. Emerged marine shell beds are common. As is to be expected, they occur more widely in flat country, but they also occur in mountainous areas in estuaries and such places. A research project on this subject has been concentrated on stratified stillwater marine beds that have been laid down behind coastal sand barriers. Such beds are deposited below low water mark, so to survey from the top of such a deposit to present low water mark provides a measure of the minimal amount of sealevel fall since the bed was emplaced. This has been done in many places in Victoria and the figure is always of the order of 6 ft in spite of various tidal ranges. In some places the shell bed is overlain by muddy estuarine deposit with such species as *Anadara trapezia* in position of growth (e.g. Seaspray, Gippsland). Stillwater marine beds are low energy deposits, and so there are no problems such as shells thrown up by storm waves.

The coast of Victoria is crossed by six tectonic provinces consisting of alternative negative structures (basins) and positive structures (horsts). From W. to E. the structures are the Otway Basin, the Otway Horst, the Central Sunklands (Port Phillip, Western Port), the S. Gippsland Horst, the Gippsland Basin, and the E. Gippsland Horst. Whether the emerged beds are on horsts or in basins, they are at about the same level and contrast with those of Last Interglacial age which in some areas have suffered deformation. While it is possible that the 500 miles of coast has moved as a unit, this is not likely, as there are active faults bordering most of these structures. However, what is found here is not found all over the globe, e.g. on the coast of California such emerged beds are not apparent as they are in Victoria.

Radioearbon dating shows that these Postglacial emerged marine shell beds in Victoria belong mostly if not altogether to the period of 4000 to 6000 years ago. Such chronometric dating allows comparison with events on land, and with shoreline structures in distant places.

## RADIOCARBON AND THE YARRA DELTA

The River Yarra has had many deltas according to the position of sealevel. The present delta is a late Quaternary structure consisting of soft gray unoxidised silt that infills Last Glacial channels and spreads over the surrounding flat areas to a few feet above present high water level. Its lack of compaction has caused many problems for bridge and harbour engineers. At the base of

this Coode Island Silt is the gravel that accumulated when the rejuvenated river was running in the floors of the channels. When the oil wharf at Williamstown had to be extended to accommodate bigger oil tankers, a difficulty existed in that it had already been built to the edge of a Pleistocene channel, infilled with sediments of inadequate bearing strength. The problem was solved by excavating the sediments to 60 ft by deep dredging, and infilling with sand from near the Brighton coast, then building the wharf on the new substrate.

The deep dredging over this considerable area revealed that the mollusc *Anadara trapezia* occupies a zone at the top of the delta and does not extend to great depth. This is not surprising because this species is at the extreme of its range in Port Phillip at present, and instead of occurring in great numbers between tide marks (as in Port Jackson for example) it occurs only in small numbers at or below low tide. So the enormous numbers of *Anadara*, their growth to such large size (up to 5 in. wide) and their position at the top of a formation rising above present sealevel indicate conditions a little warmer than at present.

At Altona the shell beds and associated sediments overlie a thick basalt flow, so minimal compaction is involved. At the base of these sediments is swamp mud, followed by beach sand over which is a marine shell bed, which passes up into beach sands again and the present swamp. Shells from the marine shell bed gave a radiocarbon date of 5560 years while a piece of wood from the base of the bed gave a date of 7040 years. This shell bed is widely spread through the delta and extends up both the Maribyrnong and Yarra Rivers into tracts which were occupied by fresh water under natural conditions. At Brunel Street, Essendon, a piece of red gum wood bored by marine borers was found in a stratified shell bed and gave an age of 4820 years. Just across the river excavations showed the extension of these shell beds over a considerable area and *Anadara trapezia* was common. The bones of a porpoise were also found there. The top of the Brunel Street shell bed is 2.4 ft above low water (MMBW datum) where the present tidal range is only six inches. As this stratified bed was deposited below low water, emergence is indicated. Estuarine muds with *Anadara* on the opposite bank rise above this level. At Power Street, South Melbourne, an excavation revealed an old channel of the Yarra with marine shells and drift wood that dated 6010 years. These dates agree with those obtained for similar emerged marine shell beds in many other parts of Victoria. The Coode Island Silt occupying the channels is of course older.

Thus a tree stump found under the S. abutment of the Spencer Street Bridge at 63 ft below low water, and peat at the same level, gave radiocarbon dates ranging from 8330 to 8780 years. Wood from 64 ft below low water mark in the new Art Gallery foundations (bore 23) gave a date of 9650 years while bore 10 on the site of the King Street Bridge yielded at 93 ft a piece of wood which gave a date of 12,810 years. At a depth of 60 ft in the channel that was excavated at the oil wharf, a diatom flora was found which is unlike that at present in the bay, but is comparable with the assemblage at Hobart where the average temperature is 5°C cooler.

Underlying the unoxidised and uncompacted Coode Island Silt is another formation that is a close parallel to it—the Fishermans Bend Silt. However, this silt was exposed during the last low sealevel with the result that it was drained, oxidised, and in places leached. This formation has not yet been directly dated. However, the Victorian Mines Department obtained a radiocarbon date on wood from the Moray Street Gravels at their base of >41,000 years. The Fishermans Bend Silt also contains *Anadara trapezia*, and is thought to be Last Interglacial in age. This species has not been seen in any older formation.

## RADIOCARBON AND EXTINCT MARSUPIALS

The first dating of a site with extinct marsupials in Australia was at Lake Colongulac in Western Victoria (Gill 1953). The sample consisted of over one pound of the small brackish water gastropod *Coxiella*, each carefully cleaned inside and out. The shells were from a fossil beach deposit comparable with the banks of shells to be seen at certain times on present lake shores. Only complete or nearly complete shells were accepted so as to avoid re-cycled material. Bones of extinct kangaroos and other marsupials were found in the same deposit. It took about one hundred man hours to prepare this sample, and members of the Field Naturalists' Club of Victoria assisted with it. In those days large samples were needed because the solid carbon method was employed. It was a disappointment that after so much work the dating was spoilt by an early atom bomb test, but when the gas method of radiocarbon dating was invented, the sample was re-prepared and a date obtained, viz. 13,700 years. This dating was the first indication in years of the age of these deposits, and was very welcome, although it had the obvious defects of being an isolated determination, and based on thin shells which could have suffered exchange on their extensive shell/air



interfaces. The date was therefore a minimal one (Gill 1968b). In spite of extensive search over many years no wood or charcoal was found in this shell bed, in the overlying tuff, or in the parna dune above, until recently when in the Colongulac Parna about 3 in. above beach level in a layer dipping lakewards at 30° there was found burnt soil, bones and charcoal, the last giving an age of  $20,100 \pm 500$  years. The bone bed is a little older. It was from this locality in 1842 that fossils were sent to Professor Sir Richard Owen at the Royal College of Surgeons in London, resulting in the first descriptions of extinct marsupials from Victoria. In spite of considerable effort over 20 years, this important site is still not accurately dated.

### AGE OF MURRAY RIVER SKELETONS

Because of the low rainfall and the alkaline nature of the soil, numerous aboriginal skeletons have been preserved in the Murray River Valley between Mildura and the S. Australian border. The high frequency of skeletal remains has been used as an argument for large populations of Aborigines in this district. This argument is only valid if the skeletons were emplaced over a short period of time, but actually no one has had an adequate idea of the range of age of these aboriginal remains. During the Chowilla Project of the National Museum of Victoria, a series of skeletons was excavated on Keera Station W. of Merbein. Some considered that this effort was of little value because the skeletons were only 'a century or two old', but five radiocarbon dates showed that the skeletons fell within the period of 4000 to 6000 years ago. Four of the dates were on the organic fraction of bones while the other was on charcoal disseminated between skeletons in a multiple burial. The skeletons thus proved to be much older than had been accepted. Interments usually took place in sandy ground where it was easy to dig, and the severe erosion that has followed the introduction of domesticated animals has caused the widespread destruction of these human remains. The evidence is being rapidly lost but it would take considerable financial resources to collect all these evidences of human occupation and date them by radiocarbon. However, a programme of sample dating being carried out at present should provide basic information about the times and places in which these Aborigines were buried.

### DATING VOLCANIC ERUPTIONS

When Professor Libby discovered radiocarbon dating, news of it came to me through Dr. K. P. Oakley of the British Museum, and I was invited

to submit two samples of 1-2 lbs of charcoal for assay by the solid carbon method. As the study of the Warrnambool district was in progress, samples were collected from aboriginal middens in that area. One was taken from Tower Hill beach, and the other from Goose Lagoon. The beach deposit overlies tuff from the Tower Hill volcano, and the date obtained was  $538 \pm 200$  years, rather young for the method at that stage. Since then methods have been refined, and the stratigraphy done in more detail. A series of dates on both marine shells and charcoal has now been obtained (Gill 1967a), and the oldest of these is a charcoal date of 5120 years for the lowest soil in the series. The charcoal was from an aboriginal midden incorporated in that soil. Underneath it is dark grey sand which overlies the Tower Hill Tuff. The eruption of this volcano has always been considered a fairly recent event, and estimates of the order of 2000 years have been given. The walls of the craters are still very sharp geomorphologically, and the ash from the volcano overlies all formations except the very recent sand dunes of the coast. A long search was made of the well exposed layers of volcanic ejectamenta, but no samples could be found within these materials by which the eruption could be dated. Absence of soil layers within the ejectamenta indicates that the eruption took place over a comparatively short period of time, so that there was no opportunity for the formation of soils between phases of activity. An effort was therefore made to obtain radiocarbon dates above and below the ejectamenta in order to define more closely the time of eruption. As the date of 5120 years is for material separated from the tuff by the dark grey sand, the time of eruption is earlier. Five miles N. of Warrnambool in the valley of the Merri River, a site was already known where an aboriginal camping place existed below the tuff. An aboriginal axe was found there in an excavation, and the accompanying bones of food animals had been turned black by the conditions of chemical reduction. A large sample of bone fragments from this site was submitted for radiocarbon dating, but there was an insufficient percentage of organic fraction for an adequate date. A 'qualitative date' of  $5085 \pm 800$  years was obtained by the laboratory that carried out the assay, but that laboratory considered that a date on the carbonate was 'far superior'. The latter gave the figure of  $6605 \pm 90$  years. The date on the organic matter is too young because the charcoal overlying the ash is older. For the time being we can regard this eruption as being something like 5500 to 6000 years ago. This example illustrates the difficulties that attend



radiocarbon dating: firstly, the difficulty of obtaining suitable materials for dating, and secondly the methodological problems. Nevertheless, the estimate of age on geological evidence was out by the order of three. Thus radiocarbon dating is able to achieve closer definition of age in spite of its difficulties. Although there is not yet a good bracket of dates below the tuff to give the maximal age, there is a good bracket above to give the minimal age.

Because Aborigines occupied this site when Europeans came, it was thought that the middens were very recent, probably not more than a few hundred years old. There are actually two well preserved occupation layers, one of the order of 5000 years ago (with hearths, bone and stone implements), and one of the order of 2800 years. As the older formation contains the bones of animals no longer in the district (Gill 1953, 1967a), important faunal changes are indicated. Our knowledge of this site has been considerably advanced, largely due to the questions raised by radiocarbon dating. The more we discover, the more we see there is to discover.

## CONCLUSIONS

Just as the faintest ink is better than the best memory, so radioecarbon dating is far better than 'a thousand intelligent guesses'. Although the amount of radioecarbon dating done in Victoria is small, it has revolutionized late Quaternary geology and archaeology; it could do the same for geomorphology, pedology (e.g. Campbell et al. 1967a, b) and some other sciences. Radioecarbon dating has created a perspective not otherwise possible at present, and has allowed correlations both near and far.

In evaluating radiocarbon dating, it is helpful to:

1. Distinguish reconnaissance dating from precision dating. Most geologic dating in Victoria so far belongs to the former category. Precision dating is illustrated by the archaeologist's series of datings through a finely stratified sequence. Reconnaissance dating grades into precision dating, but the distinction is useful.

2. Recognize grades of reliability in dating. With respect to samples, carbon is usually more reliable than carbonate, and bone collagen than bone carbonate. Thick shells are better than thin shells, and shells from an aquiclude better than those from an aquifer. Most bone collagen disappears after 5-6000 years, so that assays of older bone are likely to be negative, and those nearing the limit less reliable. When the aboriginal bone samples from the Murray River valley (30, 33, 42) were selected, a younger age than received was

anticipated, with the result that the samples were too small. Gak-1431 was measured under low pressure, and 1432-3 were diluted with dead carbon. Thus the samples were of minimal size and two methods were used, so the results cannot be taken strictly at face value. They may well be nearer the same age than the figures suggest. However, in the excavation, the sample GaK-1432 was above GaK-1433, so younger, and the radiocarbon dates were in the correct order, viz. 4170 and 4400 y respectively.

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## ZENATIOPSIS ULTIMA SP. NOV., TERMINAL SPECIES OF THE ZENATIOPSIS LINEAGE (BIVALVIA: MACTRIDAE)

With notes on its stratigraphic significance on Flinders  
Island and in the Perth Basin, Southern Australia

By T. A. DARRAGH† and G. W. KENDRICK\*

**ABSTRACT:** The terminal species of the *Zenatiopsis* lineage (*Zultima* sp. nov. Upper Pliocene (?)—Lower Pleistocene (?)) is described and a brief account given of the stratigraphic background to its occurrence on Flinders Is. and in the Perth basin.

### INTRODUCTION

Since the publication of Gill and Darragh (1963) on the subfamily Zenatiinae, further information and material of the extinct genus *Zenatiopsis* has come to hand. In particular, additional material concerning the end member of the *Zenatiopsis* lineage now enables this species to be formally described.

### STRATIGRAPHIC OCCURRENCES

The precise ages and correlation of some of the formations containing *Zenatiopsis ultima* sp. nov., are still not clearly established, and it is hoped that this account of the species may contribute to the stratigraphical correlation of late Cainozoic marine deposits in southern Australia.

The stratigraphy and problems of the Dry Creek Sands have been discussed by Ludbrook (1954, 1963) and of the Glenelg Region by Singleton (1941) and to some extent by Boutakoff (1963). However the late Cainozoic stratigraphy of Flinders Island and the Perth Basin is yet to be studied in detail, and there is little in the literature about it. The following notes have therefore been compiled as a contribution towards a stratigraphic perspective for *Zenatiopsis ultima* sp. nov.

New work reported below from Flinders Island has been done by T. A. Darragh: that from the Perth Basin by G. W. Kendrick.

### FLINDERS ISLAND

The late Cainozoic sediments of the eastern

coastal plain of Flinders Island do not outcrop, but have been exposed in the many dams and drains excavated by the Agricultural Bank of Tasmania during the development of the Furneaux Estate. The only published account of these sediments is a brief statement by Wilkins (1962) who described two Pliocene formations: the Cameron Inlet Marl and the Dutchman Coquinoid Limestone. The latter is of small areal extent, and the former changes rapidly from limestone through marl to sands and gravels. Hence one name, the Cameron Inlet Formation is applied herein to both these related Pliocene units.

The general distribution of the late Cainozoic marine deposits on Flinders Island has been studied by Darragh in the course of a recent visit. Though much detailed work remains outstanding, there appear to be three recognizable formations, two of which are widely distributed. The oldest of these, the Cameron Inlet Formation, consists predominantly of sands, gravels, coquina and marl, and is distributed from the foot of The Dutchman in the south to at least as far north as Wingaroo. The best sections are visible in the bottom of the Nelson Lagoon drain and the sides of the North Patriarch drain. The thickness is not known, though some dams excavated in the Formation are up to 13 ft deep, of which 3-4 ft at the top would represent surface soil and sand. At Wingaroo, bores up to 80 ft deep were still in what appears to have been Cameron Inlet Formation (Singleton and Woods, 1934).

The age of the Cameron Inlet Formation is

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considered to be post-Kalimnan, from the presence in it of many extant mollusc species such as *Umbilia hesitata* Iredale, *Cassis* (*Hypocassis*) *fimbriata* (Quoy and Gaimard), *Ericusa papillosa* (Swainson), and *Neotrignonia* cf. *margaritacea* (Lamarck). Also present are many 'Kalimnan' species such as *Glycymeris convexa* (Tate), *Tylospira coronata* (Tate), and *Cucullaea praelonga* Singleton, as well as certain indigenous species including *Singletonaria gilli* Marwick and *Miltha flindersiana* Singleton and Woods. From this assemblage it is concluded that the age of the Cameron Inlet Formation is Middle to Upper Pliocene.

The Cameron Inlet Formation is disconformably overlain by a younger, widespread and unnamed formation of rather similar lithology. This is however less rich in carbonate, and consequently contains no marls. This formation occurs on the north eastern coastal plain from No. 2 Road to at least as far N. as Wingaroo.

The contact between the unnamed formation and the underlying Cameron Inlet Formation has not been seen, but in dams excavated in the younger formation to the S. of No. 11 Road, worn remanié fossils derived from the Cameron Inlet Formation have been found. A little way further S., the younger formation gives way to the Cameron Inlet Formation.

The thickness of the unnamed younger formation is not known but, from the evidence of dams excavated in it, it is at least 10 ft. The mollusc fauna is essentially modern, except that the genus *Zenatiopsis* is present. Hence it is concluded that the formation is of Werrikooian age.

Specimens of *Zenatiopsis ultima* sp. nov. occur rarely and were found only in the spoil heaps of dams excavated in the very fine sands of this younger formation.

In the vicinity of Burnett Lagoon and Cameron Inlet, the Cameron Inlet Formation is overlain by a thin veneer of shell beds which we consider to be probably of late Holocene age. These are well exposed in the sides of the Nelson Lagoon drain, where they are about 1 ft thick.

#### PERTH BASIN

Drilling for water on the coastal plain near Perth has revealed the presence of previously unrecorded late Cainozoic marine deposits at shallow depths between the surface sands and clays and the underlying Cretaceous Osborne Formation.

No surface outcrops of these (post-Cretaceous) beds are known. All fossiliferous samples acquired by the Western Australian Museum were initially recovered as sludge samples from water boring

operations. The deposits contain rich molluscan assemblages which appear to represent not less than two distinct faunas.

An older fauna is recognizable in bores from the eastern side of the Perth Basin, both N. and S. of Perth, and notably in the Bullsbrook, Redcliffe and Gosnells districts. The characteristic lithology is that of a grey, strongly lithified, medium to very coarse grained calcarenite, with embedded mollusc shells and numerous small fragments of charcoal.

The samples available for study are at present small and many of the specimens recovered have sustained damage from the drill and sludge pump. Comprehensive study of the fossils from Bullsbrook-Redcliffe-Gosnells group of bores has yet to be undertaken. Specimens of the extinct, pelagic genus *Hartungia* (Gastropoda: Janthinidae) have been found in several bore samples, but no specimen of *Zenatiopsis* has yet been recovered. A provisional age of Pliocene (?) to early Pleistocene is suggested for these assemblages.

A younger fauna, which appears to be of Pleistocene age, is present in deposits underlying more central parts of the Perth Basin, particularly S. of Perth in the Jandakot and West Coolup districts, where the beds constitute a significant shallow aquifer. Specimens of *Zenatiopsis ultima* have been recovered from water bores at Jandakot, situated 11 miles S. of Perth City. Two of these bores are:

- (i) *Paulik's bore*, situated at the eastern end of Lot 41, Semple Rd, Jandakot: surface elevation  $73 \pm 5$  ft above State Mean Sea Level: depth of bore 140 ft. *Z. ultima* has been collected from 122½-136 ft below the surface.
- (ii) *Adrian's Nursery bore*, situated on Lot 18, near the corner of Thomas and Semple Rds, Jandakot: surface elevation  $75 \pm 5$  ft above State Mean Sea Level: depth of bore 130 ft. *Z. ultima* has been collected from 126-129 ft below the surface. Adrian's Nursery bore is located approximately one quarter mile south from Paulik's bore.

The characteristic lithology of the marine deposits at Jandakot (and at West Coolup) is that of a grey, fine to coarse grained, unconsolidated quartz sand, which frequently contains a high proportion of well preserved shells.

The most complete and informative sequence, obtained from Paulik's bore, consists, from the surface down, of 71 ft of non-fossiliferous sand overlying 69 ft of richly fossiliferous shell sand,



with minor intercalations of silt, algal and other limestone, pebble concentrations and, in the upper levels, much carbonaceous material. Unconformable contact with Cretaceous sediments was established in this bore at a depth of 140 ft, where drilling ceased.

The fossiliferous sequence in Paulik's bore, lying between 71 and 140 ft below the surface, is considered probably to include both transgressive and regressive deposits of the shallow neritic and littoral environments. However, satisfactory correlation of several suspected disconformities with other bores in the district has yet to be demonstrated.

The *Zenatiopsis*-bearing shell sands in Paulik's bore lie between 49½ and 67 ft below State Mean Sea Level. Near the middle of this sequence at 58½-59 ft below datum, is a pale brown friable fine-grained limestone containing shells of the non-marine aquatic snail *Physastra* (Gastropoda: Planorbidae). No marine fossils have been observed in the *Physastra* bearing matrix which is interpreted to indicate an interval of lacustrine deposition, consequent upon a brief seaward displacement of the strand line.

It is believed (Fairbridge and Teichert 1953) that the Perth Basin has been tectonically stable during Quaternary times. Lowry (1965) describes evidence of such stability from early Quaternary sediments in the southern part of the basin. It is assumed from this that the Quaternary deposits at Jandakot have also been stable since deposition, and that the sea stood at approximately 60 ft below modern level for a brief interval during the time represented by the *Zenatiopsis* bearing strata in Paulik's bore.

The main zoogeographical features of the living shallow marine fauna of Western Australia have been described by Ride and Serventy (1965). They refer to two principal elements—a northern tropical and a southern temperate fauna, which meet in "a broad area of overlap between North West Cape and Cape Leeuwin" (ibid, p. 70).

From a preliminary study of 98 molluscan species associated with *Z. ultima* from 126-129 ft in Adrian's Nursery Bore, Jandakot, it is estimated that not less than 72% of the species present are identical with or very close to extant southern Australian forms, including 17% considered to be now living E. but not N. from Cape Leeuwin. Examples of this latter group are *Glycymeris* (*Tucetilla*) *mayi* Cotton, *Limopsis tenisoni* Tenison Woods, *Chlamys* (*Equichlamys*) cf. *bifrons* (Lamarek), and *Placamen placidum* (Philippi).

Mollusc species of Indo-Pacific affinity esti-

mated by Kendrick to constitute about 20% of the living fauna at the latitude of Fremantle, amount to less than 5% of the species associated with *Z. ultima* in Adrian's Nursery Bore, Jandakot.

Compared with the living molluscan fauna from comparable environments near Fremantle, the Jandakot assemblage which includes *Z. ultima* appears to have stronger affinities with southern and south eastern Australia, and weaker affinities with north western Australia. We conclude from this that sea temperatures may have been cooler than at present during the time represented by the *Zenatiopsis* bearing sequence at Jandakot. This conclusion, combined with evidence for a sea level approaching 60 ft below modern level for part of that time, suggests that this sequence was formed during a glacio-eustatic regression of the sea, at some undetermined stage of the Pleistocene.

Of the samples so far studied, about 10-15% of molluscs associated with *Z. ultima* at Jandakot may represent extinct species. These include *Nuculoma* (*Ennucula*) *kalimnae* (Singleton), *Semivertagus capillatus* Tate, *Austromitra* cf. *multiplacata* Ludbrook, *Marginella* (*Austroginella*) *johnstoni* Petherd and species (possibly undescribed) of *Limatula*, *Cuna*, *Tawera*, *Deltachion*, *Leiopyrga* and *Bellastraea*. *Semivertagus capillatus* occurs with *Z. ultima* below the *Physastra* bed in Paulik's bore, but has not been observed above this horizon. No extinct genus other than *Zenatiopsis* is at present recognized in the Jandakot-West Coolup assemblages.

Examination of a considerable quantity of fossil material from water bores at Jandakot and West Coolup has failed to reveal any trace of shells of the genus *Pecten*. It appears probable that the fauna associated with *Z. ultima* predates the arrival of *Pecten* in south western Australia, an event which Fleming (1957) suggests occurred during the Pleistocene.

## SYSTEMATIC DESCRIPTION

### *Zenatiopsis ultima* sp. nov.

(Pl. 1, fig. 1, 4-6.)

*Zenatiopsis angustata*. Ludbrook 1955. *Trans. roy. Soc. S. Aust.* 78: 77.

*Zenatiopsis* sp. nov. Gill & Darragh 1963. *Proc. Roy. Soc. Vict.* 77(1): 185.

DIAGNOSIS: A *Zenatiopsis* with a prominent lunule and with the left bifid cardinal directed only slightly posteriorly, normal to the hinge line, or slightly anteriorly.

DESCRIPTION: Shell large and solid for the genus, elongate oval, gaping at both ends, posterior gape longer; exterior concentrically striated with growth lines. Umbones small, pointed, orthogyral, situated  $\frac{1}{4}$  the length of the shell from the anterior end.



Lunule considerably encroaching on the interior of both valves. Tooth formula (Gill & Darragh, 1963)

$$\begin{array}{c} 3a \quad 3b \\ \hline LAII \quad 2a, 2b \quad 4b \end{array}$$

Bifid cardinal 2a, 2b narrow, vertex directed slightly posteriorly, normal to the hingeline or slightly anteriorly. Internal ridge prominent, thick, flattened, extending from under the hinge plate between 2a and 2b. Pallial sinus extending to the middle of the valve. Muscle scars subequal, the posterior larger, subtriangular and elongated laterally, the anterior subcircular slightly elongated dorso-ventrally.

DIMENSIONS: (millimetres)	Length	Height	Thickness (both valves)	Umbo to anterior end
Holotype NMV P26894	103	39	16	17 (Pair)
Paratype NMV P26895	85	33	14	14 (Pair)
Paratype WAM 68-1259a, b	100	38	15	15 (Pair)
WAM 68-1259c, d	87	30	11	13 (Pair)

LOCATION OF TYPES: National Museum of Victoria. Holotype P26894, Paratype P26895, collected T. A. Darragh, D. M. Shanks and H. E. Wilkinson, 5.2.1969. Western Australian Muscum. Paratype 68.1259a, b, collected D. G. F. Smith, 1968.

TYPE LOCALITY: Dam in shelter belt, SW. side of No. 2A Road, 1.1 miles NW. of junction with No. 2 Road, Grid Reference—Flinders Island 931 762, Flinders Island, Tasmania.

STRATIGRAPHICAL RANGE: Upper Pliocene (?) to Lower Pleistocene (?).

#### OCCURRENCE:

##### 1. Flinders Island, Tasmania.

Unnamed formation. Werrikooian—Plio-Pleistocene.

(a) Type locality, 6 specimens. NMV P26894-6.

(b) Cook's dam, Block 77, Furneaux Estate, Section D, WAM 68-1259.

(c) Dam on Block 82, Furneaux Estate, Section D, 1.4 miles NE. of No. 2 Road, 0.2 miles NW. of No. 11 Road East, Grid Reference—Flinders Island 940 792, NMV P26898.

##### 2. Victoria.

Werrikoo Member, Whaler's Bluff Formation. Werrikooian-Plio-Pleistocene?

(a) Limestone Creek, Glenelg River, NMV P21840-1, P21957.

(b) Shell bed just above water level, Minnie Creek, Allotment 27, Parish of Myaring. Grid reference—Dartmoor (approx.) 240 404, NMV P26900.

##### 3. South Australia.

Dry Creek Sands, Upper horizon. Upper Pliocene. Abattoirs Bore, Adelaide. NMV P26899.

##### 4. Western Australia.

Unnamed formation. Pleistocene.

(a) Paulik's bore, E. end of lot 41, Semple Road, Jandakot. Grid Reference—1:250,000 series, sheet S1 50-2 Pinjarra 384029.

122½—123 ft below the surface, WAM 68-1448-50

133 ft below the surface, WAM 68-1446

136 ft below the surface, WAM 68-1443-4

(b) Adrian's Nursery bore, lot 18, near corner of Thomas and Semple Roads, Jandakot. Grid reference Pinjarra 383028.

126-129 ft below the surface, WAM 67-600

(c) Jandakot Cement Works bore, lot 4, Parkes Road, Jandakot. Grid Reference Pinjarra 382029.

COMPARISON WITH OTHER SPECIES: Gill and Darragh (1963) have already summarized the distinctive characteristics of this and the other species of *Zenatiopsis*: of *Z. ultima* the most important and obvious characteristic is the prominent lunule, a feature either poorly developed or generally lacking in other members of the genus. Comparison with the Upper Oligocene *Z. fragilis* Pritchard shows that the Oligocene species has its left cardinal teeth directed well to the anterior and the dorsal and ventral margins are generally curved more prominently than *Z. ultima*. The Miocene *Z. angustata* Tate has a similar tooth orientation but is a smaller and more fragile shell with a narrow, acute and curved internal ridge quite unlike that of *Z. ultima* and has no obvious lunule. *Z. phorea* Gill and Darragh (highest Upper Miocene-Lower Pliocene) has prominently posteriorly directed cardinals and either a small lunule, or none. It is probable that these species form a simple lineage whose origin is not known but was most probably derived in the Eocene from the ancestors of the earliest known New Zealand *Zenatia* (Oligocene).

COMMENTS: No other species of *Zenatiopsis* is known to have had as widespread a distribution as *Z. ultima*, which we have recorded across southern Australia from localities near Perth in the W. to Flinders Island in the E. However, it is possible that the apparently restricted ranges of the preceding species may be due to the superior records of Tertiary deposition preserved in south-eastern Australia, compared with regions further to the W.

Though no geological formation is known which contains more than a single species of *Zenatiopsis*, we can find no clear evidence which would satisfactorily account for the extinction of the genus in early Pleistocene times.

The closely related genus *Zenatina*, which was sympatric with *Zenatiopsis* in the Victorian Lower Pliocene, is still living on the eastern coast of Australia. Pleistocene generic extinction among marine molluscs is exceptional in southern Australia. In fact most of the genera of molluscs present in the Lower

Pliocene (Kalinman) of Victoria are still represented by living species on the Victorian and New South Wales coasts.

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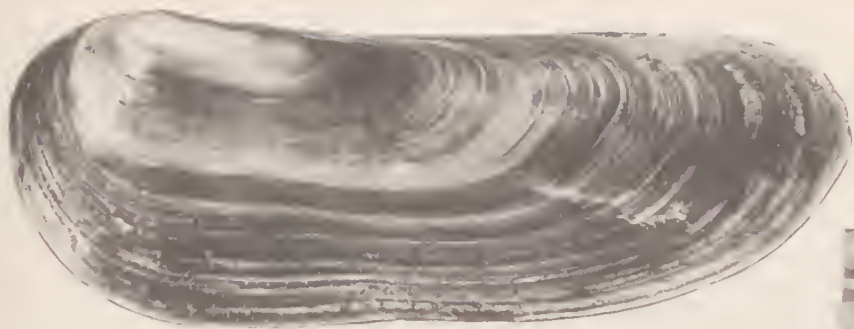
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## DESCRIPTION OF PLATE 1

All photographs by F. Guy of the Royal Melbourne Institute of Technology.

- Fig. 1—*Zenatiopsis ultima* sp. nov., P26894, holotype, left valve, Flinders Is.,  $\times 1$ .  
Fig. 2—*Zenatiopsis angustata* (Tate), P22527, hypotype, left valve hinge region, Murray River cliffs, four miles S. of Morgan, S.A.,  $\times 4$ .  
Fig. 3—*Zenatiopsis phorca*, Gill & Darragh, P21922, paratype, left valve hinge region, McDonald's Bank, Muddy Creek, Vic.  $\times 3$ .  
Fig. 4—*Zenatiopsis ultima* sp. nov., P26894, holotype, left valve hinge region,  $\times 2$ .  
Fig. 5—Ditto, P26894, holotype, right valve,  $\times 1$ .  
Fig. 6—Ditto, P26894, holotype, left valve,  $\times 1$ .





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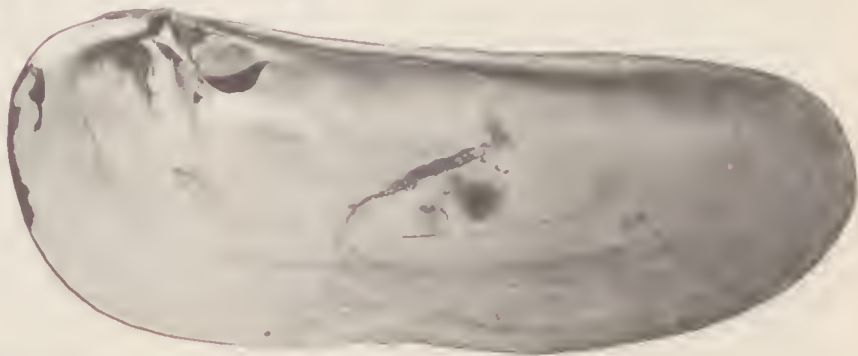
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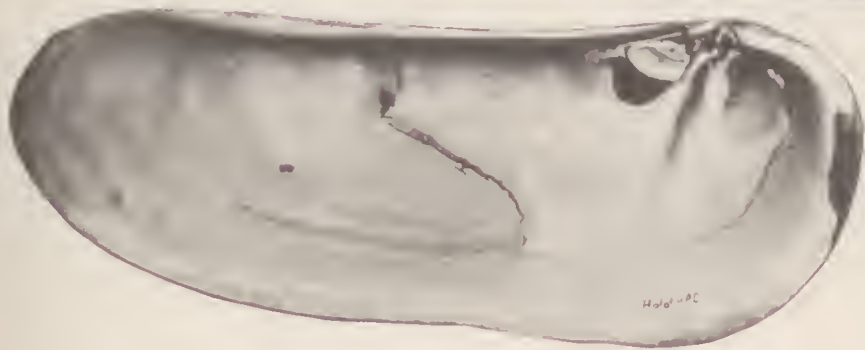
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## ON SEVERAL TRENDS OF CRYSTALLIZATION IN INTERMEDIATE MAGMAS FROM VICTORIA, AUSTRALIA

By DOV BAHAT\*

**ABSTRACT:** The ternary diagram of the system An-Ab-Or is applied to a discussion on the trend of crystallization in four intermediate magmas from Victoria. Variations are shown in the crystallization paths of the four series, depending on the composition of the initial liquids, temperature of crystallization of feldspars and the extent of reaction between the liquids and early feldspars. A correlation is made between optical properties of feldspars and their crystallization history. There is a relationship between the 2V values of the feldspar phenocrysts and the path of crystallization of their corresponding host rocks.

### INTRODUCTION

Tuttle & Bowen (1958) constructed a ternary diagram of the system  $\text{CaAl}_2\text{Si}_2\text{O}_8\text{-NaAlSi}_3\text{O}_8\text{-KAlSi}_3\text{O}_8$ , based on data in the literature on the composition of two co-existing feldspars and the host rock or the groundmass of extrusive rocks. With the aid of this diagram they discussed the general trend of crystallization in trachytic, rhyolitic, and phonolitic magmas. Important data on the feldspar ternary diagram was also provided by Carmichael (1960, 1963 and 1965).

Thirty-three intermediate rocks containing alkali feldspars were collected from the Newer Volcanic Series of the Tertiary alkaline province in Victoria. In addition to normal petrological examinations, feldspars were separated and studied by chemical and optical methods.

The rocks and their feldspar phenocrysts (Table 1) were plotted in the ternary An-Ab-Or diagram (Fig. 1). The significance of this in relation to the course of feldspar crystallization is discussed below and correlated to some optical properties of the feldspars.

### PETROLOGICAL BACKGROUND

The Victorian intermediate rocks are divided into four series: (a) Sugarloaf trachytes, (b) Macedon trachytes, (c) solvsbergites, (d) Trentham trachytes. The first three series are located around Mt. Macedon. There may have been a petrogenetic relationship between the first two series, but clear evidence to support this possibility is not available. Generally, the Sugarloaf trachytes

outcrop a few miles N. of Mt. Macedon, and the Macedon trachytes appear on the mountain itself. There is no intermingling between the two. The Macedon trachytes and the solvsbergites, on the other hand, appear in the same areas. In some cases the trachytes surround solvsbergite outcrops. Hand specimens of the two rocks occasionally appear to be similar. One rock and its feldspar phenocrysts (No. 7, Table 1) were found to have intermediate chemical compositions between the rocks and the feldspar phenocrysts of these two series. It is considered that the Macedon trachytes and the solvsbergites originated from the same magma by differentiation and stratified separation. The Trentham trachytes are a separate unit, geographically remote from the other series.

### THE MAGMATIC EVOLUTION OF THE TRACHYTES AND SOLVSBERGITES

(a) *Sugarloaf trachytes*: These are of different generations (Skeats & Summers, 1912). The section S-Si (Fig. 1) represents Sugarloaf trachytes which contain resorbed phenocrysts of alkali feldspars and olivines (samples Nos. b and c, Table 1). They are in association with alkali feldspar bearing basalts, and are believed to be products of a contaminated trachytic magma. They are particularly lime rich. Qualitative microscopic observations indicate that these rocks gave rise to two feldspar assemblages, as might be expected (Carmichael, 1963). Section Si-Sii of the line S-Sii represents Sugarloaf trachytes of a different generation. In this group the rock 23a contains

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ternary feldspar diagram the rocks and the feldspar phenocrysts show similar compositions. According to Tuttle & Bowen (1958), crystallization ends when the alkali feldspar crystals react with the liquid and attain the composition of the initial mixture. Zoning is very faint or absent, and idiomorphic forms are common. The compositions of the rocks and the phenocrysts approach the Ab-Or minimum (Tuttle & Bowen, 1958), but do not reach it. The feldspar crystallization in these rocks was not affected by fractionation, and the precipitation of a single alkali feldspar was completed under equilibrium conditions.

Edwards (1938) observed two generations of alkali feldspar phenocrysts in the solvsbergites: Anorthoclases of an early stage grown together in allotriomorphic aggregates, characterized by fresh crystals, showing indistinct tartan twins and faint zoning, and soda sanidines of a later generation, which appeared as individual idiomorphic crystals simply twinned. The present writer also observed these differences with the exception that with the aid of mineral separation techniques it was found that in fact the allotriomorphic aggregates consist of a large number of idiomorphic simply twinned crystals, thus showing that the distinction between the two generations was not clear cut. The close similarity in com-

position of the rock and the phenocrysts indicates that all the feldspars in the rock have essentially the same composition.

(d) *Trentham trachytes*: The curve T-Ti shows the trend of liquid migration of the Trentham trachytes. Each of the rocks Nos. 20 and 22 contains only a single alkali feldspar. The feldspar No. 20 is an anorthoclase cryptoperthite which has a lower content of lime than the rock. The feldspar No. 22 is a sanidine cryptoperthite which has a higher content of lime than the rock. It is considered that in these trachytes stratification and separation of the liquids into the magmas that eventually built the Blue Mountain and Mt. Wilson (Nos. 20 and 22 respectively) had preceded the feldspar crystallization (as opposed to the development of the Macedon trachytes).

Let us consider again the observation made by Carmichael, mentioned above. The acid rocks investigated by Carmichael (1960 and 1963) were generally expected to have a lower liquidus than the trachytes (Carmichael, 1965). It is expected that this would promote a crystallization of two feldspars (Tuttle, 1952). The trachytes investigated by Carmichael (1965, Fig. 2) were generally either close in composition to the two feldspar surfaces or were particularly anorthite rich (10% anorthite or more): again, conditions

TABLE 1. Chemical Analysis of Trachytes and Solvsbergites and Their Feldspar Phenocrysts

	<u>2</u>	<u>3</u>	<u>7</u>	<u>12</u>	<u>14</u>	<u>16</u>	<u>17</u>	<u>20</u>	<u>22</u>	<u>20a</u>	<u>b</u>	<u>c</u>	<u>23</u>	<u>23a</u>
SiO <sub>2</sub>	66.84	65.23	64.73	61.40	60.60	60.70	60.64	57.60	58.60	57.63	51.52	54.06	55.95	55.02
Al <sub>2</sub> O <sub>3</sub>	17.80	17.00	17.50	20.02	18.80	18.53	18.60	18.81	19.20	18.61	16.58	17.13	18.10	19.02
Fe <sub>2</sub> O <sub>3</sub>	2.38	3.85	4.03	1.39	3.49	4.24	4.32	2.67	3.91	2.36	2.38	6.10	8.28	7.34
FeO	0.82	1.18	0.49	2.56	1.94	1.65	1.40	4.41	2.15	4.08	7.68	3.55	0.50	2.18
MgO	0.04	0.26	0.11	0.44	0.68	0.90	0.65	0.89	0.50	0.69	4.03	3.05	3.05	1.57
CaO	0.35	0.46	0.41	0.76	1.55	1.91	1.77	2.05	1.45	2.33	6.10	4.88	1.77	2.78
Na <sub>2</sub> O	6.54	6.63	6.63	5.87	5.72	5.13	5.43	6.02	6.82	5.77	4.11	3.97	4.64	4.11
K <sub>2</sub> O	4.70	4.79	5.19	5.85	5.49	5.19	5.37	5.33	5.23	5.38	2.99	3.92	4.96	3.69
TiO <sub>2</sub>	0.05	0.15	0.10	0.74	0.72	0.69	0.78	0.62	0.15	0.55	2.15	1.95	2.17	2.64
P <sub>2</sub> O <sub>5</sub>	n.d.	n.d.	n.d.	0.39	0.35	0.35	0.25	0.37	0.06	0.28	0.82	0.48	0.16	0.74
MnO	0.06	0.09	0.08	0.02	0.16	0.13	0.12	0.21	0.12	0.21	0.13	0.20	0.10	0.14
Total	99.58	99.64	99.27	99.44	99.50	99.42	99.33	98.98	98.19	97.89	98.49	99.29	99.68	99.23

Norms of feldspar components in rocks (recalculated to 100 wt%):

Or	31.67	31.36	33.63	38.95	36.24	36.29	36.18	35.67	34.19	37.54	25.26	26.85	37.26	32.18
Ab	66.43	66.16	64.24	59.39	57.50	54.65	55.53	55.54	62.19	51.94	49.09	46.29	52.85	54.45
An	1.90	2.48	2.13	1.66	6.26	9.06	8.29	8.79	3.62	10.52	26.65	26.86	9.89	13.37



TABLE 1. Chemical Analysis of Trachytes and Solvsbergites and Their Feldspar Phenocrysts (cont'd)

	<u>2</u>	<u>3</u>	<u>7</u>	<u>12</u>	<u>14</u>	<u>16</u>	<u>17</u>	<u>20</u>	<u>22</u>	<u>20a</u>	<u>b</u>	<u>c</u>	<u>23</u>	<u>23a</u>
Feldspar components (recalculated to 100 wt%):														
Or	32.14	32.27	31.58	31.40	31.75	31.95	34.48	33.18	34.39				36.87	
Ab	66.66	66.29	64.93	57.81	56.40	57.11	57.69	60.31	61.71				55.05	
An	1.20	1.44	3.49	10.79	11.85	10.94	7.83	6.51	3.90				8.08	
2V	46(1.5)	45(1.5)	53(1)	52(1)	57(2)	57.5(2)	48.5(2)	58(2)	43(2)				39.5(1)	

that naturally promoted a crystallization of two feldspars. Feldspar No. 20 (present study) crystallized under different conditions, from a sodium rich trachyte magma containing a moderate amount of calcium (5%-10% anorthite). It is possible that under such conditions sanidine did not start to precipitate, and consequently, with a continuous reaction of the early plagioclases with the liquid, a lime-poor anorthoclase was developed and the liquid was enriched with calcium. In this rock apatite is in abundance (Edwards, 1938), and the excess of calcium in the rock was accommodated in apatite and aegerine-augite.

When the liquid of rock No. 20 was changed into the liquid of rock No. 22 by lowering the calcium content (accompanied by an increase of the Na/K ratio), a precipitation of sanidine was promoted and the expected crystallization took place (Carmichael, 1960). Early plagioclases were completely resorbed and a single sanidine (No. 22) was formed.

Thus, one can observe several paths of feldspar crystallization in the Victorian intermediate magmas. Generally, with a continued equilibrium cooling of a trachytic magma the early crystallized plagioclases are resorbed by the liquid, enriching it with sodium and calcium. This is partly balanced by the reaction of the early sanidines which enriches the liquid with potassium and impoverishes it in calcium and sodium. Commonly (Carmichael 1963), the end result tends to be a single feldspar with a liquid impoverished in calcium (No. 22). If the reaction is long enough, the compositions of the rocks and feldspars would approach similarity (solvsbergites). In liquids having a moderate amount of anorthite (5%-10%) which are sodium rich, if there is a low rate of plagioclase resorption in the liquid, the end result would be lime rich anorthoclases (Macedon trachytes). Alternatively, depending on the temperature of crystallization and the composition of the rock and initial plagioclases, with a continuous reaction of the plagioclases with the liquid, lime-poor anorthoclases would be

developed (No. 20). Crystallization in the latter two processes can be accomplished without a precipitation of sanidines.

### PHASE DIAGRAM CONSIDERATIONS IN RELATION TO OPTICAL PROPERTIES OF FELDSPAR PHENOCRYSTS

Carmichael (1960) examined the optical properties of feldspar phenocrysts of some Tertiary acid glasses and classified them for the purpose of his study according to their twinning. Feldspars twinning only on the Carlsbad, Manebach, and Baveno laws (although very fine, shadowy, but optically indeterminate lamellar twinning was persistent) were called alkali feldspars, and either sanidine or anorthoclase according to their symmetry. Feldspars twinning on the above laws and also on the albite, albite-Ala, and Carlsbad-albite laws, and in which very fine lamellar twinning was rare or absent, were called plagioclases.

A somewhat different classification seems to be more characteristic for the Victorian feldspars. All the feldspars having simple Carlsbad twins have also low 2V values (Tables 1 and 2, Bahat, 1970). They are considered to have been crystallized essentially as sanidines. In some cases faint zoning or shades of tartan twinning indicate that the sanidine developed from a plagioclase or anorthoclase which had been nearly completely resorbed in the liquid. All the feldspars from intermediate rocks investigated by the writer, having prominent tartan twins and no simple Carlsbad twins, also had optic axial angles higher than  $2V = 48.0^\circ$ . These feldspars in most cases were also lime-rich. They are considered to have been crystallized as plagioclases or anorthoclases.

Judging by the chemical and optical properties of samples Nos. 4F and 7F (Carmichael, 1960, Table III), and assuming that they are representative anorthoclase phenocrysts of the Tertiary acid glasses, one observes that they differ from the feldspars of the Victorian intermediate rocks by having the combination of low 2V values and



high content of anorthite ( $2V = 48^\circ$  and  $41^\circ$ , and  $An = 7.8\%$  and  $10.8\%$  respectively).

A correlation between optical observations made on the feldspars and equilibrium diagram considerations gives a new significance to the optic axial angle. By studying the evolution of the liquids of the various rock series and their feldspars, one can see a repetition of cycles. The Trentham trachytes are an excellent example of a cycle which produced sample No. 20 with a high  $2V$  value,  $58^\circ$ , in early stages of the evolution, and sample No. 22 with a low  $2V$  value,  $43^\circ$ , in a late stage of the liquid evolution. In the Macedon trachytes one observes that the feldspars Nos. 14 and 16, which were crystallized at relatively high temperatures, have high  $2V$  values,  $57^\circ$  and  $57.5^\circ$  respectively. Feldspar No. 17, which is richer in potash and presumably had its later stage of crystallization at lower temperatures, has the lowest  $2V$  value of the Macedon trachytes,  $48.5^\circ$ . The crystallization of all the solvsbergites was very similar, probably under similar temperature conditions, and can hardly be called a cycle. One exception to this was feldspar sample No. 7 which is a lime rich feldspar with a high  $2V$  value,  $53^\circ$ . It is believed that this feldspar was crystallized in a magma in which a separation between the Macedon trachyte and the solvsbergite liquids was not completed. If so, it would be in harmony with the above correlation.

It can be concluded that the  $2V$  value does not indicate an absolute temperature, but that it does indicate whether the host rock belonged to a high or low temperature stage of a certain cycle (early or late stage respectively). Sample No. 17 belonged to a low temperature stage of the Macedon

trachytes, but this can be at a still higher temperature than sample No. 20, which belonged to a high temperature stage of the Trentham trachytes.

## ACKNOWLEDGMENTS

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The writer is most grateful to Dr. R. J. W. McLaughlin for valuable discussions and to the members of the Geology Department, University of Melbourne, for the encouragement which they extended to him during his stay.

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## NOTES TO SPECIMENS IN TABLE 1 AND IN THE TEXT

Numbers of specimens in Table 1 and in the text, as well as the data on composition of feldspars and  $2V$  values, correspond to identical specimens reported by Bahat (1969, Table 1). Analyses for rocks Nos. 20a, b, and c are quoted from Edwards (1938), pages 264 and 274 (omitting values of  $H_2O^+$ ,  $H_2O^-$ , and trace elements). The figures for specimen No. 23a are from a new analysis. The analyses which are not quoted from Edwards were made by the writer.

The types of rocks and locations of all the specimens which appear in the text are as follows: 2 and 3, solvsbergite, Camels Hump, Mt. Macedon; 7, solvsbergite, Fawkners Hill, Macedon district; 14 and 16, trachyte, Turritable Falls, Mt. Macedon; 17, trachyte, a small peak 40 yards SW. of the Camels Hump; 20, trachyte, Blue Mountain near Blackwood; 22, trachyte, Mt. Wilson, Blackwood; 20a, trachyte, Babington Hill, Trentham district; 23, 23a, b, and c, trachyte, vicinity of Sugarloaf Hill, NE. of Woodend.



## THE SEARCH FOR AN EVOLUTIONARY PHILOSOPHY OF MAN

By RICHARD D. ALEXANDER\*

When J. B. S. Haldane suggested that Darwin may have stirred the greatest philosophical revolution of all time, he was voicing a sentiment destined to gain widening acceptance. G. G. Simpson (1964) described Darwin's book, *On the Origin of Species*, as the most important one of the past few centuries because it changed man's attitude toward himself. In a classic discussion of man's biological nature, Simpson (1966) noted:

The question 'What is man?' is probably the most profound that can be asked by man. It has always been central to any system of philosophy or of theology. We know that it was being asked by the most learned humans 2000 years ago, and it is just possible that it was being asked by the most brilliant australopithecines 2 million years ago. The point I want to make now is that all attempts to answer that question before 1859 are worthless and that we will be better off if we ignore them completely.

These may seem harsh words, but their appropriateness becomes more apparent, not less, as one explores the early philosophical literature in light of what has been learned since 1859. Simpson went on to explain his meaning: that whatever we may think or believe about man must be consistent with what we know about evolution and man's history. Prior to 1859 there simply was no general explanation of life, including man, that made any real sense or was consistent with the growing body of knowledge.

Because of its all-encompassing character, evolutionary theory is by nature philosophical in its application to man. But, as Simpson and others have also pointed out, Darwin himself is not generally considered a philosopher. In this apparent contradiction lies part of the reason that I and many other evolutionary zoologists, who may seem little qualified to discuss the question 'What is man?' or to argue philosophy, feel obliged to enter the discussions on these topics. The technological explosion and the population explosion have suddenly removed such considerations from the academic ivory tower; indeed they have forced

man to the brink of a revolution in his view of himself which, if he survives to see it through, will surely overshadow any that has gone before. Overpopulation and war have emerged as global problems, no longer just the problems of this or that nation or this or that society. Simultaneously, they have become the personal problems of every individual with sufficient comprehension to be concerned about his own future and that of his children and his grandchildren. Men are seeking general explanations of human behaviour, and for the first time in history there is real and widespread anxiety in the search. 'What is man?' and what we do with the fragments of answers that we are able to gather are no longer simply the most profound questions facing man, but the most practical and urgent ones as well. My belief in this urgency is the first reason for my selecting the title that I did for this lecture.

The second reason has to do with the history of evolutionary thought. During the first 70 years following Darwin, the concept of the gene, and of the particulate nature of heredity, was incorporated into evolutionary theory. Otherwise, religion and evolution fought a rather dull battle, waves of anthropomorphism followed waves of anti-anthropomorphism, determinism was repeatedly linked with blind induction and so alternately fell into and out of favour; and, perhaps, little else of particular importance to our present topic actually happened.

During the next 40 years, however, evolutionary biology came to life, beginning with the publication in 1930 of Fisher's *The Genetical Theory of Natural Selection* and following through syntheses on selection by Haldane (1932), Sheppard (1958), and others; on speciation and reproductive isolation by Dobzhansky (1937) and Mayr (1942); and on evolution in general by Simpson (1950, 1964) and others.

It has taken a while for the new information and ideas to filter down. In the late 1940s, when

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I was a student taking courses in philosophy, psychology, and biology, none of them had anything to do with the others: evolution was never mentioned in the philosophy course, and only as a nasty word in the psychology courses; behaviour was scarcely mentioned in the biology courses, least of all in connection with evolution, for which flesh and bones seemed the only candidates.

Something quite different is true today. Evolution is finally being recognized by the everyday biologists as their guiding principle, as the thread of continuity, the liaison amongst all of the different kinds of investigations of living materials. Increasingly, biologists are aware that each of them is testing, clarifying, or expanding some aspect of the theory that all features of life have resulted from the evolutionary process as we understand it today. Evolution has become the topic of the first lecture in introductory biology as well as the last; and selection and adaptation are concepts that must be mentioned almost every day in any modern biology course.

If, as I believe, there is no place to seek general explanations of human nature but in the evolutionary process, then we are fortunate that during the past four decades our understanding of this process has grown so immensely. Perhaps—just perhaps—evolutionary biology is ready to meet the challenge that is being thrust upon it.

The third reason for my topic specifically concerns behaviour, which has had perhaps the most erratic history of any aspect of the study of living things. For decades behavioural study was scarcely even respectable in biology, largely because no one knew how to make behavioural observations repeatable and cumulative (therefore 'scientific'), but also because man's behaviour was the last of his characteristics that he wanted placed into an evolutionary context. This reluctance had a considerable effect on the study of animal behaviour. In America, particularly, psychology more or less took over the study of behaviour in the early part of this century, and because of the preoccupation of psychology with man, the comparative and evolutionary aspects all but disappeared and the whole science literally became the study of something called learning. There was no real justification for this, and, perhaps predictably, the concept of learning ultimately came to be used by many as if it were essentially synonymous with epigenesis (or all of the events of ontogeny in which environment and heredity interact). To a degree, the trend is understandable, for the most indirect connections between genotype and phenotype are those between genes and behaviour: behaviour springs

from morphology and physiology, which are by definition, therefore, closer to gene action. For a very long time the last thing anyone thought should be done to understand an animal, not to say man, was to try to relate its behaviour to natural selection and evolution. There was even doubt in some quarters that behaviour evolved!

What had been forgotten was that, while behaviour may be farthest from the genes in terms of how the phenotype (or the animal itself) functions, it is as well closest to selective action. More than anything else, it is the behaviour of an animal that actually causes it to be favoured or disfavoured. If an animal cannot survive subzero temperatures, it may be able to dig a burrow, build a warm nest, or go where temperatures are higher; if food is depleted in one place it can move to another; and so on. In a 'behaving' organism, few aspects of morphology and physiology can be selected except in terms of some intervening or mediating behaviour. One has to wonder why zoologists were so slow to accept that predictability can be increased about even some very subtle aspects of animal behaviour more swiftly by comparing them in terms of life functions, selection, and adaptation than by any other means. I believe there is evidence that our resistance to viewing ourselves and our own behaviour as evolved phenomena has been significantly involved.

The above point perhaps needs illustration (see also Lorenz, 1952, 1966; Lack, 1966; Williams, 1966a; Morris, 1967; Tinbergen, 1968). In some ways we humans are like our domesticated animals because both of us now live in environments so remarkably different from those in which many of our most distinctive characteristics evolved. Although this fact is sometimes used to argue that it is useless to search for the selective action that made man, it can also be used to support the converse argument that we may be able to understand ourselves only by harking back to the nature of our early, different environments.

Anyone who has owned a dog for long will be aware of the propensity of canines for vomiting and re-consuming the results. I am sure that a large number of dog owners look upon this behaviour as some kind of perversion, perhaps deriving somehow from the unnatural environment in which dogs now live. In fact, it has played a vital role in the particular kind of parental behaviour displayed by a variety of wild canines: coming home with a full stomach and regurgitating at the den is the way that canine parents bring food back to their babies in the interim period when the puppies are too large to fare best on milk alone and too young to be taken along on

hunting trips (Scott, 1967; Kleiman, 1967). Vomit is the weaning food of young puppies. With this knowledge we may suddenly acquire reasonable hypotheses about details that might possibly be observed—why one sex might be more likely to vomit than the other, for example, or why a bitch with a litter is likely to vomit near the nest at least once when her puppies are a certain age (I emphasize that these are speculative possibilities based on my own observations and presented for illustrative purposes only; further, there must be numerous aspects of this behaviour, already known to canine biologists, that I am not mentioning).

This sort of insight, which in this case can come only from knowledge of the selective context in which dogs evolved (perhaps now only from studying relatives of dogs), changes our attitude toward dogs and toward this aspect of their behaviour. Many aspects of our own behaviour may similarly seem to be mere perversions, or products of civilization, when in fact they are a great deal older and more complex than this, and perfectly reasonable or understandable in terms of our evolutionary history. Despite many arguments to the contrary (Skinner, 1966; various writers in Montagu, 1968), I believe that the great problems in regard to human behaviour exist because so much of our behaviour, yet today, falls into this category; and I will refer specifically to war, a collective activity that most individuals profess to abhor, and over-reproduction, still being aggravated by the whims of single individuals or pairs of individuals, though feared almost universally by man in general.

The final reason, and perhaps the principal one, for my choice of topic is my feeling that an inexcusably small percentage of the people writing about man today have done their homework on the facts and the theory of evolution. I am not sure why this should be true, but it is disheartening, particularly when one is reading what has been written by eminent and influential people brought together in discussions aimed at solving massive social or political or biological problems. Regarding human behaviour, it sometimes seems that every possible stand has been taken on every possible issue, with no one having any particular reason other than personal opinion for choosing one side or the other. To parade examples can become a lengthy and involved procedure, and I will cite later what I believe to be some of the more important ones. Here I will use a single example, not a particularly critical one, but perhaps instructive, partly because it is not so obvious.

In his recent book, *The Naked Ape*, Desmond

Morris (1967) attempts, with creditable success in some regards, to assist man in thinking of himself as a product of evolution and a relative of other primates. One of his arguments, however, is that breast size and shape in the human female are the results of sexual selection that has run counter to the nursing function of the breast: 'The enlarged female breasts are usually thought of primarily as maternal rather than sexual developments, but there seems to be little evidence of this' (p. 70). Because men like hemispherical breasts, he suggests, they have caused the evolution of breasts that among other things make it difficult for babies to nurse without smothering (p. 106). Morris seems to overlook the point that sexual selection is not really unlike any other kind of selection: thus, if any primitive male's ideas of female beauty corresponded to the kind of breast that was maximally effective in nursing and motherhood, that male would have a reproductive advantage over any of his fellows whose art had less to do with function. This, moreover, is aside from the point that his argument suggests (though it does not require) the unlikely condition of unmated females in primitive societies, since it says nothing about the reproductive advantage of the female whose breasts were more effective in nursing, and who became pregnant rather regularly even though she may not have been considered the belle of the village.

Part of Morris's explanation is evidently inconsistent with evolutionary facts and theory, and the burden of proof is upon him that his original interpretation which supports this portion of his thesis was accurate—that breast shape and size in a general group of humans actually derived their distinctiveness through selection in a direction detrimental with regard to the nursing function. His counter to the 'slight' evidence against his view is apparently his point (p. 70) that 'Other species of primates provide an abundant milk supply for their offspring and yet they fail to develop clearly defined hemispherical breast swellings'. But this seems an inadequate comparison, for several reasons. First, few primates nurse their offspring for the period of several (2-6) years that studies of primitive societies indicate was the case in pre-civilization man—apparently only chimpanzees (Lawick-Goodall, 1968), and probably orangutans and gorillas, approach this condition. Second, he evidently refers to breast size and shape in females that have nursed little or not at all, for numerous published photographs of African, Australian, and Pacific Island women suggest that breasts on mature nursing mothers do not remain spherical and are not as different in shape from those of some other primates as



he seems to indicate. Finally, variations in breast size and shape in very young (or pre-nursing) females, even though not necessarily seeming to correlate with those occurring in mothers who have nursed uninterruptedly for, say two years or more (a difficult situation to discover today in some parts of the world), may nevertheless indicate variations in subsequent potential in the nursing function. Morris's argument may derive from the statement that 'breast size and milk production are not related' (Freedman, 1968) which recurs in the literature. Evidently, it is derived from an examination by Engel (1941) of breasts of 26 British women who died following childbirth. Engel found that some large breasts contained less and lower quality mammary tissue than smaller ones; no information was given on the relative obesity of the women. Engel's sample is small, and there are other data indicating a correlation between breast size and milk production (Maey et al, 1930, 1945). The only demonstration that would really be pertinent to the question raised here is that breast size is not correlated with either amount (or quality) of milk produced or the length of time that adequate quantities of milk could be produced under the conditions (for example, of nutrition for both mother and child) in which the human breast reached its present state. I emphasize that there is no incompatibility between suggestions that breast size (1) correlates (at least roughly) with lactational capability and (2) operates in sexual selection. Nor is it unlikely that large breasts that were inferior to smaller ones in regard to lactation have occasionally been favoured in sexual selection. The problem arises only when the sexual selection is supposed to conflict with the nursing function dramatically and for a long period, and when such selection is supposed to account for the distinctiveness of the human breast.

## EVOLUTION: FACTS AND THEORY

Having given at length my reasons for complaining about progress in the search for an evolutionary philosophy of man, I now come to the question: Where does one begin?

Attempts to interpret man's nature in terms of his evolutionary history may utilize insights gained from several different sources: fossil evidence; comparisons involving either man's closer relatives among the primates or other species that have evolved parallel behaviour; comparisons of different populations of men; comparisons of behaviour (or other characteristics) at different ages, and between the sexes at the same ages; and inferences drawn from comparing man against all other forms of life. The last comparison implies that

broadly general or universal aspects of the evolutionary process are involved. This is where I wish to begin. Because of the nature of the disagreements and misconceptions concerning basic aspects of evolution, I believe that it is necessary to establish common ground at the most fundamental level, and that is with acceptance of the fact of organic evolution. By this I mean simply the acceptance (1) that inheritance occurs (like begets like; the reproductive or genetic materials can be passed from generation to generation without change); (2) that mutations occur (the genetic materials do change occasionally, and these changes are in turn transmissible); (3) that selection occurs (all genetic lines do not reproduce equally); and (4) that isolation occurs (all genetic lines are not able, for various extrinsic and intrinsic reasons, to interbreed freely).

All of these four phenomena have been demonstrated repeatedly and can be demonstrated at will, as can their interaction; all of them have been dissected, or are being dissected, in elegant fashions; no living things have been demonstrated to lack any of them or, to my knowledge, are suspected to lack any of them. We have come full circle when biologists such as Muller (1966) and Smith (1966) can conclude that the criterion for life is the potentiality of evolution by natural selection.

If what I have just stated is the essence of the fact of evolution, then, one may ask: What is the theory? In simplified form, the theory is that these component parts, more or less as we understand them today, are sufficient to account for all characteristics of all life: in other words, that everything we see of life about us has been produced by the interaction of heredity, mutation, selection, and isolation. There are ancillary phenomena of great importance, of course—recombination being perhaps the most prominent—but all of these can follow from the interaction of the four more basic features (see also Simpson, 1969).

Acceptance of the above facts means acceptance that man has evolved and is evolving, and leads directly to the hypothesis, using Simpson's (1966) words, that: 'Man owes all his characteristics to their gradual and very slow accumulation because they worked better, because they promoted most successful reproduction and continuance, through all the varying circumstances in which our ancestors lived.'

Perhaps my reasons for beginning at such an elementary level are now apparent: we have passed already to a statement that is probably not a good representation of the working hypothesis of most biologists, not to say the general public.



I think there are two reasons for general failure to accept this hypothesis. First is the persistent notion that evolution is 'only a theory'. The basic facts given above, and the mountains of data supporting them, are still unappreciated by the holders of this view. Second is the recurring suggestion that there are basic flaws in evolutionary theory which excuse us from considering its application to any truly important problem such as understanding man (e.g., Moorhead and Kaplan, 1967; Boulding, 1966). This second kind of disparagement is a much more complex and subtle phenomenon, and I am going to digress for a moment to discuss some examples.

Perhaps the most prominent vehicle of the 'basic flaw' arguments has involved the fact that no one has been able to demonstrate a relationship between (1) which mutations occur in the hereditary materials of the germ cells and (2) which ones will later be saved, or, to say it with teleological implications, which ones will be most useful, or will enable their possessors to outcompete. What this really means is that the causes of mutations (chiefly, at least, radiation) and the causes of selection (Darwin's 'hostile forces' of predators, parasites, diseases, food shortages, and climate) appear to be unrelated: there is no known feedback between them. This is a most important point, for it not only bears on the question of how selection affects mutation rates, but it has been the subject of some confusion regarding the definition of randomness in the direction of mutation. For example, many of the participants in a recent symposium titled *Mathematical Challenges to the Neo-Darwinian Concept of Evolution* (Moorhead and Kaplan, 1967) were evidently operating on the assumption (which seems naive, if only from a chemical point of view) that 'randomness' in connection with gene mutations means that all directions of change are equally likely. Accordingly, among other things it seemed to them that man could not evolve from primeval ooze in the time available. Sewall Wright explained this mistake in his contribution to the meeting, noting that the randomness in gene mutations to which the evolutionists refer is in relation to directions of selection.

It may be instructive to quote two additional authors in this general context. Medawar (1968) has written that our ignorance of the actual mechanics of mutational changes represents a serious deficiency in modern evolutionary theory. No one would deny the very great importance of learning why certain mutations occur and others do not, or why some occur more frequently than others. But, except for the cumulative influence of selection, this is a chemical problem: if the

cause-effect chain is as indirect as seems to be the case, then selection can only save favourable mutations, delete unfavourable ones, and adjust mutation rates as a result of the relative proportions of the two kinds of mutations and the rate of change in the environment. In such case, this area of our ignorance is no more a serious deficiency in *evolutionary theory* than it was a serious deficiency in evolutionary theory a few decades ago to be ignorant of the actual mechanics of heredity while knowing, nevertheless, that faithful reproduction does occur. Again, I do not wish to downplay the very great significance of learning about the nature of DNA, but to place it in perspective. Evolutionary theory could and did pass through many successive stages of refinement solely through knowledge of how accurate reproduction can be, and with total ignorance of its actual mechanics. As we shall see later, this kind of argument may have great relevance to more current problems, such as how to establish appropriate hypotheses regarding predictability and alteration of the course of behavioural ontogeny while still ignorant of cause-effect relationships within the specific ontogenetic process.

Koestler (1967), as still another 'basic flaw' critic, supposed that he had hit upon a remarkable and previously unappreciated 'missing link in orthodox theory' in noting that any genetic innovation undergoes its first test in its effect upon the existing ontogenetic, physiological, and morphological machinery. I am sure that biologists in general will wonder why Koestler thinks this is a new idea; Williams (1966a), for example, gives an excellent review of the hierarchy of environments in which new mutations are tested. All aspects of phenotypes exist solely because the genetic materials responsible proved themselves in past external environments. Because any genetic change may improve any aspect of the phenotype at any ontogenetic stages as well as reduce its fitness or destroy it as Koestler implies, we may also wonder if Koestler himself is quite clear on the significance of the point he is trying to make.

The nature of the 'direction of mutation—direction of selection' link in the cause-effect chain between molecules and organisms may be important for another, somewhat incidental reason: because it marks, perhaps better than anything else, a significant boundary between biology and chemistry. King and Jukes (1969), for example, are probably working about as close as one can get to this boundary from the chemical side when they investigate the largest molecular changes in the genetic materials that are selectively neutral because they are chemically 'synonymous'.

These several examples may seem peripheral to

my topic, but they have previously been used, purposely or more or less inadvertently, to cast doubt upon the adequacy of evolutionary theory. There is an important difference, often overlooked, between criticisms that identify areas of ignorance in the various levels of refinement or detailing of the process of evolution and those which suggest that some serious and basic flaw exists in the general theory. I do not believe that any recent argument in the later category has been successful.

As a final point, it is important to understand that there is no known feedback relationship between mutations and effectiveness in reproductive competition because this fact, together with the dramatic effects of simply altering directions of selection (particularly upon domestic animals) reveals that natural selection is the predominant guiding force in evolution. It is almost entirely upon selection that one must focus his attention if he wishes to trace or understand a particular pathway in the course of evolution, such as that leading to man.

### NATURAL SELECTION AND REPRODUCTIVE COMPETITION

Natural selection, or differential reproduction, inevitably implies competition of one sort or another. Before considering different kinds of competition and their relative importance, it may be appropriate to set the stage by describing one of the chief problems concerning the effects of selection upon humans.

Characteristics described as uniquely or most decidedly human are likely to be related to behaviour, and, accordingly, to the complexity of the functioning of man's remarkable and relatively huge brain. Brain size increases correlate across various time levels with fossil evidence of increasing complexity of social organization and the appearance of various cultural phenomena. In spite of arguments based on variability in modern man's brain size, there can be little doubt that the increases in cranial capacity, which can be traced from australopithecine to modern man, are directly related to the increases in complexity of brain function that have resulted in modern man being so different from other living primates (Washburn, 1959; Caspari, 1963; Holloway, 1966; Rensch, 1968; Lancaster, 1968). Crude as it may be, this is still one of our best indices as to when, and how fast, man became a man.

In my opinion, there are three especially interesting questions regarding evolutionary changes in the size of man's brain:

1. How could man's brain increase in size so rapidly from australopithecine to modern man?

In 50,000 to 150,000 generations, or roughly the span of two million years, the volume of the brain case tripled, going from around 500 cubic centimetres to around 1,500 cubic centimetres.

2. What caused the increase in brain size and (particularly) the complexity of its function to go so far beyond that of all other primates?

3. Did the brain stop increasing in size some 50,000 to 100,000 years ago, as is frequently supposed, and, if so, why?

The last of these questions rests upon the skimpiest sort of evidence, namely that the fossils of Neanderthal and Cro-Magnon men suggest that their brains were at least as large as ours are today (Vallois, 1962). Of course they may not have been as complex, but this does not entirely erase the question of why the size increase (apparently) ceased. Evidence from some quarters has suggested that intellectual capacity is not increasing in modern man, and may even be decreasing; other reports, however, indicate that the opposite is more likely (Reed, 1965). Clear evidence of differing rates of change or reversals of direction at any time level, of course, would make any unusually rapid or long-term unidirectional changes all the more intriguing.

An assertion commonly heard in this context, that the pelvis of the human female reached a limit relative to increases in the head size of infants, seems either to stem from a naive view of evolution or to beg the question. Selection always involves compromises of conflicting advantages and disadvantages, and it is difficult to argue that any particular feature of the phenotype has actually reached an absolute physical limit. I am unaware of reasons for supposing that further broadening of the pelvic opening, or other morphologic and ontogenetic changes permitting larger brains, are beyond the realm of possibility if the behavioural situation had continued to favour them. Furthermore, there is probably enough variability among modern women in this regard to discredit the argument that an upper limit of any sort has been reached.

The second of the above questions regarding changes in brain size, which seems to have received the least attention, is in some ways the most interesting of the three. Why is man so different from his closest relatives? Implicit are one or two additional questions: (1) Why has man not speciated? Or: (2) Why have his closest relatives become extinct? I am not so concerned with the first question as with the point that, in the case of rapid evolutionary change of interest here, the second question applies whether or not the extinguished close relatives were members of the same species.



Regardless of the indirectness of the relationship between man's genotype and those aspects of his phenotype that we generally refer to as 'intellect', what we know of the history of changes in man's brain size and in the complexity of his behaviour leads us to the tentative conclusions (1) that variations in intellect were subjected to unusually intense selective action, (2) that this selection was consistent across long periods, and (3) that it carried man's intellectual capabilities right up to their present condition.

There are data of another sort to support this idea. Erlenmeyer-Kimling and Jarvik (1963) have noted that if all of the available data on intelligence test scores are compared, matching individuals of all possible relationships from identical twins to essentially unrelated individuals, and correcting so far as possible for environmental effects using test scores of related individuals, including identical twins reared together and apart, the results are what would be expected if (1) there exists a strong residual of test score differences owing to genetic differences and (2) multiple genes are involved in an additive fashion. These results can scarcely fail to reinforce the idea that generalized increases in intelligence were favoured rather consistently across a long period in man's history. Such a case is just the sort in which one expects the relationship between genotype and phenotype to become increasingly direct, and the accumulation of numerous genes affecting the character in question.

Now let us consider in more detail the ways that natural selection operates. Selection is differential reproduction of alternative genes, or alleles, within populations. It is brought about by differential mortality and differential fertility induced by predators, parasites, diseases, food shortages, and climate. As I see it, there are four possible kinds of such intraspecific competition:

1. Differential reproduction without direct interaction or confrontation between competitors.
2. Partial or complete exclusion of competitors from the best (or only) sources of food, mates, and shelter through aggressiveness and territoriality.
3. Elimination of competitors or potential competitors by killing them.
4. Cannibalism, or the elimination of competitors with food being obtained without additional risk or energy expenditure.

There is an argument for combining the last two forms of competition, but I do not intend to refer to accidental or incidental cannibalism, and the difference between aggression that functions solely in eliminating competition and aggression

that functions chiefly, or partly, in food-getting seems sufficiently fundamental to warrant listing them separately. Furthermore, there will be a greater difference in reproductive potential, on the average, between a well-fed cannibal and his former competitor than between a not so well fed non-cannibal and the competitor he has just killed. I am using the word 'function' here in the sense of Williams (1966a) to mean 'evolved function'—that is, to refer to the probable context of selection, and as opposed to incidental effects.

I emphasize that the focus here is on reproductive competition. Confusion and disagreement about competition (cf. Milne, 1961) may partly stem from failure, particularly by ecologists, to recognize that other aspects of competition are, in one sense or another, secondary or tertiary to this one; and, as Williams points out, it is difficult to see how any organism can escape reproductive competition of one sort or another.

It must be quite clear that the questions of which of the above kinds of competition were involved in man's evolution, which were predominant, and what were the sizes and compositions of the units among which different kinds of competition operated are critical in man's attempts to understand himself. To take what may seem an extreme example, there is no great likelihood that a species in which the chief method of competition has involved only indirect interaction among competitors for 100,000 generations will closely resemble in its behaviour a species in which cannibalism and war have been predominant for as long. Yet just this amount of difference occurs between some of the existing views of man's history.

The different forms of reproductive competition are not equally prevalent in all species, or in all situations in the same species, and the last three, at least, involve different intensities or directness of selective effect. The first, differential reproduction without direct interaction, probably occurs in every species of organism, whether or not the others also occur. This is what is happening when my neighbour has five children and I have two, and neither my neighbour nor I do anything to influence the other's family size or its success. I suspect that this kind of interaction predominates chiefly among simple organisms and in cases in which the influence of Darwin's hostile forces is minimal. One must be careful about interpreting the apparently peaceful interaction of such as my neighbour and me, for, among other things, we may be conspiring—or behaving as though we are conspiring—against some groups external to our neighbourhood.

(I am reminded that someone told Freud about



people living on islands in the South Pacific where the climate was benevolent, food was plentiful, and there were apparently no significant predators, parasites, or diseases, and then remarked that as a consequence these people lived in complete and peaceful bliss. Freud said that he found the last part difficult to believe, and in this particular case he was right. As Captain Cook and a good many others would testify, some peoples living under such seemingly idyllic conditions have formed the most ferocious, war-waging, cannibalistic societies known on earth.)

The second form of competition—exclusion of competitors from food, mates, or shelter through aggression or territoriality—is widespread among animals with complex behaviour (such as vertebrates, arthropods, and cephalopods), and it may be universal among such organisms when commodities are in short supply.

Evidently, in animals with sufficiently complex behaviour, increasing population densities and accompanying shortages of commodities will cause shifts toward the more direct forms of competition. In animals able to predict and plan on a grand scale (man), furthermore, one would expect action to be taken before commodities have actually been exhausted, or before differential reproduction or development of power differentials operate in their disfavour. In all likelihood, we need not fear starvation on a global scale nearly so much as we need to fear the reactions of powerful segments of society to such an impending condition.

The most direct forms of competition, killing of conspecifics and cannibalism, seem rarely to have been observed among animals in general, and it is usually difficult to obtain evidence whether observed cases represent evolved functions or incidental effects resulting from some other kind of selective action—a most important distinction. Reports on cannibalism are not abundant for most kinds of animals; yet man's fossil record is usually interpreted as indicating that some amount of cannibalism occurred more or less continually all through his history at least as far back as the australopithecines (Dart, 1948; Blanc, 1962; Freeman, 1964).

I find it difficult, for two reasons, to be confident about what has been said in much of the anthropological literature tending to diminish the extent and significance of cannibalism. Some investigators (although few of those writing today) have seemed to avoid discussing its prevalence, as if it were a subject best forgotten, and most still use its ceremonial nature to cover the question of function. Ceremonies or rituals associated with cannibalism or any other aspect of human

behaviour may have their chief significance in the encouragement and guiding of an activity functional in some quite different context. It may be easier for a mother to feed her newborn baby to an older child during famine if a ceremony emphasizes the value of this practice to the older child; or, on the other hand, it may be easier to keep the practice of eating newborn infants from growing outside this role and thereby incurring a reproductive disadvantage. It may be easier to keep cannibalism outside one's group if ceremonies keep it related strictly to war and the defeat of one's enemy. In either case there may be reproductive value in either the nutritional or the aggressive aspects of the practice, or both. Even a false belief in the value of eating an enemy's brain, as a further example, could possibly assist cannibalistic groups in destroying and thus out-competing non-cannibalistic groups regardless whether genetic differences in this or other regards exist between them.

Part of the problem is in interpreting the general relationship of cultural change and genetic change. A cultural practice may reinforce, thwart, or not affect a reproductively advantageous behaviour. On the average, however, those features of culture which either reinforce reproductive advantages or replace them with greater ones will outlast those which do not. This is what Simpson (1964) meant when he said (p. 99) that '... culture in general is biological adaptation and ... ethnologists could resolve some of their squabbles and find the common theoretical basis that eludes them if they would just study culture from this point of view'.

All aspects of the phenotype, after all, whether physiological, morphological, or behavioural, are susceptible to alteration and improvement by the specifics of the developmental environment; and all such flexibility is a result of genetic selection. Culture differs from other aspects of behaviour in this regard in being both communicable and cumulative among individual organisms. As behaviour is, in this sense, less directly genetic than morphology and physiology, so is cultural behaviour less directly genetic than behaviour as a whole; but it is not independent of genetic change and natural selection.

At the risk of repetition I must say something here that is basic to my argument. Some investigators caution against possible errors in interpreting evolutionary history almost to the point of rejecting every effort as fruitless. It is possible so to interpret Rappaport (In: de Reuck and Knight, 1966, especially pp. 40-41). Clearly man is not nearly so simple as to be understood solely in terms of added intellectual capacity. But in what

terms? If in terms to be gleaned solely from immediate contingencies or his present situation (cf. Skinner, 1966; Thompson, 1969), why do we continue to be perplexed and helpless in the face of persistence of aspects of man's individual and collective behaviour abhorred by nearly everyone, particularly, perhaps, by parents and teachers who seem to be in the best position to alter them?

Questions of the sort posed in the preceding paragraphs can ultimately be answered. Each such answer cannot fail to have massive effects upon man's view of himself, effects that would be difficult if not impossible to achieve in any other fashion. The more complex man is, the more appropriate is this entire argument. Evolutionists are often accused of oversimplifying man, and they often do: I accuse those social scientists who believe man can be adequately understood without taking full account of his evolutionary history of the same error.

### INSTINCT AND LEARNING

As Gilula and Daniels (1969) and Berkowitz (1969) point out, the current search for general explanations of human behaviour (or for explanations of widespread, apparently uncontrollable or undesirable behaviour) has led to a repolarization of opinions that does not differ greatly from that prevalent decades or even centuries ago. Without exaggerating very much, we may call these two positions the 'everything is learned' theory (e.g., most writers in Montagu, 1968) and the 'ineradicable instinct' theory (e.g., Lorenz, 1952, 1966; Ardrey, 1966). It is not surprising that worldwide problems in human behaviour should produce support for singular or unitary explanations such as that they stem from 'ineradicable instincts'. Nor is it surprising that the same idea acquires support from persons who realize that they personally lack any notion of how they acquired tendencies or desires to do certain things, and from persons at least dimly aware that the plunge toward world disaster seems to have been affected little by conscious efforts of mankind despite the armies of social scientists who have been preoccupied with learning theory for the past several decades.

Proponents of the 'everything is learned' hypothesis insist that supporters of the contrary view are also looking for an explanation which relieves them of personal responsibility for their actions; and in somewhat less rational fashion they have even argued that, in any case, their opponents are helping people searching for such excuses. It is hardly reasonable to accuse a man of being a social darwinist because he argues for certain causes of historical events, unless the

appellation has nothing to do with his views of what is desirable for the present and the future of man. It is even less reasonable to imply that he must not analyze human behaviour if his analysis—right or wrong—can be distorted or misused by others. Yet all of these arguments can be found, mixed in with more appropriate ones, in the essays edited by Montagu (1968). One is reminded that the whole idea of man having evolved was cast into disrepute because Hitler distorted it; and it was cast into disrepute for the followers of Karl Marx on an entirely different basis because he distorted it.

It is true that the 'ineradicable instinct' theory seems to call for an entirely different course of action from the 'everything is learned' theory. In the first case we may think of sublimating or substituting; in the second of simply eliminating the appropriate learning situation. But is it really so simple? What does 'everything is learned' really mean? First, we might note that some learning situations are conscious, and perhaps extensively recallable, while others may be completely non-conscious or at least non-recallable. Superimposed on this variation there are differences in the likelihood of occurrence of learning situations that will lead to particular kinds of behaviour. If 'everything is learned', then we must suppose that widespread or universal behaviours are produced from widespread or universal learning situations. The problems are to identify them and, if the behaviour is deemed undesirable, to eliminate them from man's environment. But we seem as yet unable to eliminate whatever circumstances bring about aggression and over-reproduction. At least, we have not been able to do it on purpose, and we have not been able to describe an environment in which we can be reasonably certain that all men could live together without aggression and without overcrowding.

It is not theoretically incompatible with any version of learning theory that some learning situations may themselves be ineradicable, or very difficult to eradicate, from the human environment. I suspect that most biologists accused of supporting the 'ineradicable instinct' theory would settle for having their views interpreted as support for 'ineradicable learning situations'. Whether or not even this is a reasonable hypothesis, it is clear that many different kinds of ontogenetic influences of behaviour occur, that some occur more often than others, and that genetically different organisms respond differently to similar learning situations. Different organisms learn different things, or learn the same thing more or less easily or quickly. To the extent that learning situations leading to aggression or over-reproduction are



difficult to eliminate from the human environment, it may be most practical—or even essential—to think, at least temporarily, in some terms other than those of merely adjusting the developmental environment so as to eliminate the acquiring of aggressive tendencies.

Supporters of the 'ineradicable instinct' theory have been guilty on occasion of making their decision on the basis of what are commonly called 'isolation' or 'deprivation' experiments. One rears a bird, for example, in total silence, even deafening it. If the bird later sings normally, its song is said to be 'innate' or 'inherited', and it presumably enters or approaches the category of ineradicable instinct. But such experiments can never tell what actually leads to the behaviour: they can only reveal that certain stimuli are not involved, or at least not necessary. Of course, the stimuli selected for exclusion are those the investigator has reason to believe are most likely involved in producing the behaviour; one can only say that in those cases in which the behaviour is not influenced by the deprivation, the investigator's ideas in this regard were incorrect, and some as yet unidentified sequence of stimuli was responsible for the behaviour. Deprivation experiments have not identified two fundamentally different kinds of behaviour; rather, they suggest that, in terms of developmental basis, there are several not so fundamentally different kinds of behaviour. They have also exposed unsuspected complexities in behavioural development. It is unfortunate that ethologists chose to deal with behaviours discovered to have cryptic developmental bases by simply labelling them all 'instinctive': and it is even more unfortunate that psychologists in general chose to interpret such labelling as an argument for developmental simplicity or obviousness. Part of the reason for this may be that cryptically developed behaviour typifies many organisms that we consider to be relatively simple. I believe that man's behaviour as a whole has a more complex developmental and neurophysiological basis than that of any other animal; but I also believe that some of its most prominent and influential aspects may have cryptic developmental bases as do some of those behaviours labelled 'innate' in other animals. Some of these behaviours will be difficult to understand developmentally and, at the least, extremely difficult to eliminate universally or on a wide scale.

Unlike Montagu (1968, p. xiii), I believe that all behaviour involves both heredity and environment. Several writers have emphasized recently that when one speaks of any trait as being 'inherited', the remark is sensible only if one is actually speaking of differences in phenotypic

expressions: traits, as we use the term, are actually differences. It may seem at first that many differences in phenotypes, particularly in organisms as flexible as man, are independent of heredity. If, however, two persons decide to learn to play the lute at the same time, it is unlikely that identical teaching and practice will have identical effects regardless of previous experience. With some knowledge of family musical aptitudes, one could probably predict more often than not which way the difference would lie, even if the subjects had been adopted away from their musical or non-musical families at birth. This would indicate that heredity was involved, and not so subtly or indirectly after all, in behavioural differences brought about by instruction and practice in each case. Genotypic identity is rare in humans and, as Dobzhansky (1964) has put it, 'Heredity is particulate, but development is unitary. Everything in the organism is the result of the interactions of all genes, subject to the environment to which they are exposed.' This observation, or hypothesis, suggests that different loci do not act independently in the organism, so that in fact heredity cannot be totally eliminated as a variable in any given circumstance by considering only one or a few loci.

There are some kinds of behaviour in which either heredity is more involved or the instructing and practising experiences are more universal, or both. World problems resulting from human behaviour will frequently involve behaviour falling into these categories because they concern widespread or universal aspects of behaviour. To the extent that this is so, it is not naive to seek general explanations with even relatively low predictive value; the more universal the behaviour, the more significant is an explanation with a particular level of predictive value.

Because heredity and environment are two phenomena, each of which influences behaviour, they are the sources of most dichotomies in referring to behaviour. It does not follow that there is justification for dividing all behaviour into two or a few types on the basis of development and then insisting that man lacks any of the types (See also Hinde, 1968). It is misleading to say, as some recent writers have, that aggression has been 'trained out' of some group of humans when in fact no one knows precisely why aggression has not been displayed in that group; nor is it proper to refer only to one kind of aggression in such a case and imply that whatever was influential in deleting that one kind of aggression in that one small group necessarily applies in any way to other kinds of aggression or to entire nations or the entire world population.



I do not think it is necessary to solve completely this problem of the developmental basis of potentially dangerous behaviours of man before some predictions can be made and some courses of action taken that will begin to alleviate our present problems. I think, further, that understanding of general evolutionary theory, together with current information from the social sciences (for example, see Berkowitz, 1969), will automatically improve man's chances of solving his behavioural problems. Such understanding, moreover, is probably prerequisite for effective investigations of the ontogenetic bases for human behaviour.

### SELECTION AND ALTRUISM

Now let us return directly to the hypothesis that man is a product of selection; that all of his characteristics accumulated because they best promoted reproduction. Let us see how easy it is to accept this hypothesis for man.

The most basic assumption deriving from this hypothesis concerns what is commonly called altruistic behaviour, or the act of contributing to another's welfare at some net expense, however slight, to one's own well-being—more specifically, contributing to another's chances of reproducing at some expense to one's own chances. Presumably because it seems the most likely path to peaceful co-existence, altruistic behaviour is held up, among men, as being extremely desirable. There are some other possible reasons for its promotion, which I will leave aside for the moment. In any case, it seems to be one of man's fondest ideas about himself that he tends to think of others first.

However, since evolutionary change proceeds as a result of differential reproduction of genetic alternatives within populations, to the extent that man is a product of evolution, we must at least begin with the hypothesis that, like all other organisms, he is reproductively selfish and never, except by accident or error, truly altruistic.

In this hypothesis, he may be expected to love his neighbours only to the extent that they can assist in his own reproduction, preferably at the expense of theirs. He may be expected to behave as if he is free to do, not whatever does not interfere with the freedom of others, but whatever will indeed interfere with the freedom of others without interfering with his own—whatever, in other words, has a better than average chance of bringing net gain, or whatever will bring the largest net gain to himself, his mate and his offspring—especially to his offspring. It should not be the giving, but the ultimate getting that means the most to him.

He should not care a whit for the perpetuation of the species, only for the perpetuation of enough of it to insure the well-being and continuity of his own genetic line.

Of course he may be expected to avoid revealing all such aims as these, whether or not they be conscious aims, for such revelations are themselves likely to reduce his reproductive possibilities, however slightly. (To anyone thinking that my behaviour here runs counter to this hypothesis, since I am concerned about saving man as a species, I refer to my earlier remark that when a problem becomes a world problem it also, unavoidably, becomes a personal problem).

Man, in short, should really have but one 'instinct', and that is the reproductive instinct (which in his case is synonymous not with sex, but with sex, parenthood, and grandparenthood). There should be only functions subsidiary to this one in his makeup, both individually and collectively. Whatever he may consider, furthermore, even if he chooses to give it names like beauty and poetry and art and charity, should have reached their levels and modes of expression as a result of selection that is nothing more nor less than differential reproduction. (J. B. S. Haldane, 1963, said he accepted this hypothesis for most things, but not for the appreciation of melodies, for which he could think of no function whatsoever. He added that he himself was tone deaf.)

Even self-preservation should be subsidiary to reproduction. Men should be more likely to give their lives in defence of their offspring than in any other situation. Indeed, if we wanted to get very precise about it, comparisons of actual cases should show that there is less reluctance to make such sacrifices (1) as dependent offspring become older, and the parents' energy investment in them increases, and (2) as the parents age, and their likelihood of further reproduction decreases. This general kind of hypothesis is being examined for other kinds of parental animals (Lack, 1966, 1968; Williams, 1966b).

Please remember that I am stating hypothesis—but the kind of hypothesis that most biologists would assume, automatically and without question, for any animal other than man. Acceptance of this hypothesis turns the focus upon the avenues through which reproductive gain has usually been realized by humans; upon how much of the species may generally have been necessary to ensure perpetuation of any individual's genetic line; and upon how man's various characteristics have related to reproductive gains.

I do not imply that the kinds of responses being hypothesized here necessarily depend upon conscious consideration, upon predictions, plan-

ning, or anything of the sort. What an extraordinary problem is that of understanding the significance of conscious learning versus non-conscious learning; of how the different levels or kinds of consciousness have been manipulated by selection specifically to include certain aspects of man's behaviour and to exclude others. Semantic and other difficulties notwithstanding, this is my personal idea of the most exciting of all biological problems. The extent to which the interpretations of behavioural scientists have been obfuscated by this problem can scarcely be over-emphasized. Murphy (1957) is an example, and Fox (1967a) gives an excellent review of the problem in his discussion of incest. I think it is a startling revelation that extensive discussions of the problems of understanding consciousness may fail even to mention evolutionary considerations (e.g., Miller, 1942).

Perhaps, by now, you are saying to yourself: But the hypothesis of non-altruism does not adequately describe man's behaviour! Many men truly are selfless! What about the soldier who falls on a grenade and saves his comrades?

I suggested earlier that there are other possible reasons for promoting altruism than mere peaceful co-existence. Any time there is an external 'enemy' that threatens all, whether it be biological or physical, then altruistic behaviour reaches relatively extreme levels. Such circumstances are those in which profitable returns from 'pseudo-altruism' (seemingly altruistic behaviour which actually yields a reproductive gain, on the average) are most likely, and also those in which pseudo-altruism may be expected to 'spark over' most frequently into truly altruistic, reproductively disadvantageous behaviour (which is how I would categorize the behaviour of the soldier above). Tinbergen (1968) has noted that for the Dutch the sea has served the function of an external enemy; winter may have similarly influenced communal aspects of Eskimo behaviour; and other examples could be cited. Freud suggested that the maintenance of communistic societies depends upon the reality of external enemies, and I believe that the behaviour of such societies, apparently involving conscious manufacturing of such enemies in some cases, supports this suggestion.

There is a curious paradox in the idea of conscious attempts to revise the structure of society as a whole toward Utopian ends. Such plans seem inevitably to involve some special and prominent forms of altruism; yet, in the absence of other 'enemies', the success of Utopias, particularly in terms of persistence, seems always related to the extent to which the members have been able to

view, and to continue viewing, all or some large part of the remainder of society as an external force hostile to their system. Perhaps there is no more succinct commentary on the dilemma of man.

Altruism toward one's close associates is probably never promoted more strenuously, or achieved more completely, than during wartime. Wars are conducted between groups of people. Agreement seems universal that man evolved in groups larger than the smallest reproductive units, as I will discuss later, and this enormously complicates the problem of interpreting selective action on man's behaviour. If one cannot survive or reproduce outside a group, or cannot do so as well (and there are no other reasons for living in groups), then acceptance and approval by the group is prerequisite to reproduction, even if such approval is acquired only at great risk. I suggest that such considerations lead to a view of man's apparent altruism slightly different from that currently present. Extreme altruism may not be undesirable in itself, but to the extent that it is a symptom of alliances of violence or desperation, it can scarcely be viewed as a simple concomitant of peaceful co-existence.

If man is truly a product of evolution, then reproductive selfishness is the most basic aspect of the hypothesis with which any serious attempt to understand him must begin. If we were merely to consider that the challenge is to discover whether or not or how far man may deviate from reproductively selfish behaviour, how he may express his behaviour in terms of this requirement, and what aspects of it may exist in the various levels and kinds of consciousness of which man seems capable, then I would suppose that at last we are on the proper course. I do not see how anything less than this can be satisfying, knowing what we do about evolution and man's history.

Two questions arise at this point: First, how does one arrive at the conclusion that all organisms are reproductively selfish, and, second, how does one transfer such an idea, involving genetic change, even as a working hypothesis, to something as developmentally labile as the behaviour of man?

In spite of wide use of the term 'species adaptation' by biologists (some version of it must occur in every biology text!) and in spite of implications that individual organisms possess a great deal of behaviour aimed at assisting the species or the population even at the expense of the individual showing the behaviour, every such case has alternative explanations in keeping with selection theory. Most have now been studied thoroughly enough to show that the non-evolutionary inter-



pretation was faulty, and, even more important, no scheme has yet been advanced by which genetic variations resulting in truly altruistic behaviour can spread through a population (Hamilton, 1963, 1964a & b; Williams, 1966a).

When a genetic variant that is good for the individual is also good for the population or the species, then it may become universal and be called a 'species adaptation' on that account. But the value to the population or species is not a cause of the selective action but an incidental result of it: if a characteristic is good for the individual (in terms of immediate reproductive competition) but bad for the species (in terms of decreasing, or not increasing, the likelihood of indefinitely long survival) it will lead to the species' extinction unless some change in this connection occurs as the gene spreads (Fisher, 1958). If differential extinction of more or less isolated populations of a species causes genetic change sufficiently rapid to more than counterbalance a reverse genetic change within populations owing to differential reproduction of individuals, then the overall direction of change within the species as a whole can be said to result from 'group' selection (Williams, 1966a, discusses this point). But the disadvantage to the populations of the direction taken by selection within them cannot in itself alter that direction (Wright, 1948). Overpopulation, as exemplified by man, is an appropriate example.

### REPRODUCTIVE SELFISHNESS AND OVERPOPULATION

Human overpopulation is the most frightening problem in the world today. I find myself viewing it almost as a disease that is spreading across the planet, and one that may yet prove fatal, partly because it is the chief agitator toward use of weapons that can destroy all life. Every other human problem—war, resource depletion, pollution, crime—fluctuates in seriousness with the severity of overpopulation. This problem is so awesome, and its solution necessarily involves attitudes so alien to the ways that humans have always thought and believed and behaved, that until recently people have been as reluctant to discuss it seriously, and to contemplate it, as they are to discuss or contemplate suicide, or the possibility that there is no life after death and all the consequences of such a realization. Never in the enormously long and complex history of life has it been advantageous to restrict one's reproduction.

In recent years, some biologists and popular writers have promoted the suggestion that man is the only animal lacking 'built-in' population

controls (Wynne-Edwards, 1962; Koestler, 1967), and, in one subtle guise or another, this idea has invaded biological thought on a surprisingly broad scale. The argument is that the reason other species do not keep on increasing as man is doing is because the reproductive individuals reduce their output during lean seasons or years in order to prevent overpopulation, mass starvation, and perhaps extinction of the species. Every biologist who suggests that selection directly favours certain population sizes or densities is supporting this argument, and so are nearly all geneticists who define fitness in terms of populations and then discuss it as an adaptation.

What would happen to genes that facilitated such altruistic behaviour in individuals carrying them? Of course they would be outcompeted by alleles permitting or causing greater reproduction leading to greater overpopulation. There is no way that imminence of extinction, even of the entire species, could change this result.

The same fate would befall genes residing in genotypes which simply gave their phenotypes sufficient latitude to behave altruistically on occasion—that is, when and if more conservative alleles were present as competitors. This is the answer to the most general sort of question that can be asked concerning the flexibility of the phenotype in relation to selection. Perhaps no aspect of development is more widely misunderstood in its relation to selection and evolution than this one.

Most of the examples cited to support the kind of altruism connected with overpopulation involve parental animals which reduce the number of young actually produced and are thereby able to bring more offspring to reproductive maturity, and which will fight in the securing and holding of sufficient territory to protect and feed their young. In other words, one is only witnessing a particular form of reproductive selfishness which has the incidental effect of reducing population density at certain times in the life cycle, but tends overall to increase population numbers and thus density. Man's population density is going up not because he alone lacks a built-in population control, but because he keeps reducing the effects of predators, parasites, diseases, food shortages, and climate. One predicts that in any long-lived parental animal, such as man, some abatement of reproduction will result from increasing population densities, or from accompanying phenomena such as various kinds of tension, strife, and hardship. In the absence of conscious considerations (such as apparently only man can indulge), such behaviour must often have yielded greater lifetime reproduction for the individuals showing it.



Perhaps such behaviour is reflected in the birth rate retardation in the USA that has surprised demographers recently. It seems the height of naiveté, however, to suppose, as some biologists and anthropologists do, that this kind of braking action will lead inevitably to populations kept stable at reasonable levels by birth rates that are continually fitted to the lowest attainable mortality rates.

Even in societies in which newborn infants reportedly are cannibalized to sustain older children or the mother (Basedow, 1925; Bates, 1938), the result is almost surely that the parents bring more offspring to reproductive maturity. If, among predacious birds, stronger nestlings kill and eat weaker ones during food shortages (Ingram, 1959), this behaviour could also increase the parents' reproduction. In some ants, the feeding of fertile eggs to developing young is standard behaviour at certain stages of colony development; we may assume that this is a form of cannibalism that is also selectively advantageous. All of these cases are probably examples of the fourth kind of competition described above, and I believe it likely that many additional instances will ultimately be discovered.

Instead of being the only organism lacking a built-in damper on population increase, man is more likely the only one which has evolved a capacity for truly altruistic reproductive behaviour in relation to overpopulation, even though this capacity is just an incidental effect of the selective action that produced it. Theoretically, at least, man could use his ability to predict and to plan consciously to reduce his reproduction and save his species. Whether or not such behaviour occurs in such a way as to be accurately judged altruistic, there seems to be no evidence yet that any man has actually reduced his reproduction for other than selfish reasons.

Perhaps the most important kind of point that I am trying to make is that man may not be able to use such abilities to save himself until he understands them and himself in terms of natural selection. In other words, I suggest that the only effective way for man to discard any part of his evolutionary background that he decides he does not like is by first understanding it thoroughly—by lifting it into his conscious consideration. This argument is slightly but significantly different from those which imply that man ought to find out about his evolutionary history so that he will know what kinds of things he will be unable to accomplish, or unable to change. The latter approach is one that derives from the supposition of an ineradicable aggressive instinct in man.

Suppose we were to proceed as if convinced

that man is, basically and historically, a reproductively selfish organism. Would this affect our strategy against the disastrous overpopulation into which the world is already starting to plunge?

Among the suggestions of recent writers on this topic, three seem reasonable and immediately possible: (1) giving to all people everywhere the means and the right to delay reproduction and to restrict the sizes of their families (religion seems to be the only major barrier), (2) removal of financial or other tangible rewards for increasing one's family size (the problem is how to do so without depriving children), and (3) educating people concerning the current trends in population growth and their probable results (this step, I believe, cannot fail to foster the attitude that large families may bring doom upon the world and are therefore unacceptable). The importance of the third suggestion probably cannot be overemphasized, though for a reason that may not be obvious. The desire for approval among one's associates is a selfish reason for refraining from having a large family, and an extraordinarily powerful one. Legislation is merely an extreme way of registering disapproval by providing concrete and specific punishments, and, in fact, many writers see no alternative in this case (e.g., Hardin, 1969).

Lengthening of generation time by delaying reproduction ought to be stressed here because its effect on population growth is generally unappreciated (Cole, 1954), and it may represent a less painful way to ease population growth rates than by simply reducing family size (Ehrlich, 1968). Delayed initial reproduction would almost surely reduce births per marriage as well, though the extent of this effect, when it results from induced or compulsory delays in reproduction, would be difficult to predict.

The problem, however, aside from some kind of legal recourse, is not so much in identifying behaviour that will reduce the likelihood of overpopulation, but in getting individual people to do the things that we already know will change the trend. Unlike some others, I see no basis for believing that the population explosion can be affected significantly by appealing to the consciences of individuals in an altruistic sense. At most, not enough individuals can be expected to respond quickly enough to cause an appreciable effect. At this moment in history I doubt that one person in a thousand, or even in a million, limits his reproduction in order to help save the world. There are always more personal—and more selfish—reasons. It is one thing to frown upon one's neighbour's oversize family, or to keep one's family small because of possible embarrassment,

quite another to consider limiting one's brood so that a neighbour will be better able to raise whatever size of family he may already possess. We can scarcely fail to appreciate Ehrlich's (1968) suggestion that the individual who insists that he has a large family simply because he loves children could have expressed that quality better by adopting some of the unloved, already produced children rather than by contributing to the unhappiness of a future, overcrowded world in which children must live.

I believe that better understanding of man's evolutionary background will reinforce the suggestion that effective approaches to overpopulation must depend upon appealing to responses that are basically selfish as far as individuals, or individual pairs of parents, are concerned, and upon responses which may be importantly involved, though not through any conscious efforts of man, in the prominent cases of static (or nearly static) populations in some nations today. Perhaps we will come to view as beneficial in this regard such things as the presence of complex and multiple gradations of opportunities towards aspects of some kind of the 'good life', whose attainment is clearly dependent upon degrees of financial and other achievements inversely related to age of initial reproduction and family size. Potential parents must be convinced that by reproducing early and increasing their family size they are restricting their children's and their own opportunities in significant fashions. Perhaps the relatively minor penalties for having large families in some affluent countries and the absence of significant or attainable rewards in terms of standards of living in some impoverished countries are both contributing to overpopulation. How to provide adequate rewards in countries already in desperate throes of overpopulation may be an extremely difficult problem. No easy solutions to overpopulation have been proposed, however, and some experts believe it is already too late to avert disaster on a world-wide scale.

## AGGRESSION

The argument that man is reproductively selfish also carries implications of special importance in interpreting interactions among people, both as individuals and as groups, particularly for that group of interactions generally labelled as aggressive, and therefore for the threat and reality of war.

Because relatively little intraspecific violence is observed among animals in the wild, many investigators have assumed that man's propensities to violence and war are products of civilization. One argument is that they are simply the results of

frustrations and tension—remove these, and the aggression is removed (Russell and Russell, 1968); another suggests that they are 'learned', or result solely from child-rearing practices and other forms of socialization. Still a third argument is that man has an ineradicable aggressive instinct (Lorenz, 1966). Gilula and Daniels (1969) and Berkowitz (1969) discuss all three of these hypotheses in relation to some current problems.

In this connection it has also been stated, quite recently and by some eminent evolutionary zoologists, that, while most or all animals possess built-in restraints against the killing of members of their own species that function in the welfare of the species as a whole, man lacks such built-in, species-preserving restraints, and this explains the rise of aggressiveness in civilized man. In *King Solomon's Ring*, Konrad Lorenz provides the clearest statement of this argument that I have found (pp. 197-198): 'When, in the course of its evolution, a species of animals develops a weapon which may destroy a fellow-member at one blow, then, in order to survive, it must develop, along with the weapon, a social inhibition to prevent a usage which could endanger the existence of the species . . . There is only one being in possession of weapons which do not grow on his body and of whose working plan, therefore, the instincts of his species know nothing and in the usage of which he has no correspondingly adequate inhibition. That being is man.'

One cannot doubt that in species which evolve lethal weapons, inhibitions against unprofitable use of those weapons evolve as well. How could such weapons be used to the detriment of their possessor? Against a mate. Against offspring. When would their use against a reproductive competitor in the same species be detrimental? Only when that competitor will be useful later on, say, to help kill large game or to help defend against predators; when he can be eliminated from competition through a very much lower expenditure of energy, say, by threat alone; and when he too possesses lethal weapons with which he may mortally wound or disable even though himself be ultimately killed in the process.

No animal lives as long with a single mate as do most men (although many are at least as monogamous). No animal keeps its offspring around it and tends them for as long a period as does man, and as has man, apparently, for at least the last two million years. No animal has acquired weaponry even remotely as powerful as thermonuclear bombs and refrained from their usage as long as has man. Again, I believe that Lorenz and other biologists who support his argument are exactly wrong. Not only do animals in



general lack species-preserving inhibitions of aggression, but man, who clearly has the most elaborate and complicated selfish inhibitions to aggression in the animal kingdom, may also possess the ability to use his intellect purposely and directly to preserve his species from the destructiveness of his aggression. Again, it is an incidental effect of selection, and he has not yet demonstrated that he can use it.

A possible reason that observers of animal aggression have been misled is because in many battles between apparently devastatingly armed beasts, little or no damage is done. I believe that careful observation will show that this is often the case because each individual 'knows' (1) not only how to use his weaponry but also precisely how to defend against that of his opponent, and (2) when it is to his advantage not to press the fight further. The worst kind of animal on which to press an attack with a low probability of gain, after all, is one that has lethal weapons; if you kill him but receive a mortal or disabling wound in the process, you are certain to lose rather than gain. Lions and tigers, one of Lorenz's chief examples, seem not different from nations with nuclear weapons in this regard. Writers who have interpreted the small number of actual deaths in warfare between neighbouring tribes, as described, for example, in Matthiessen (1962) among New Guinea peoples, as evidence of some kind of inhibition to killing, miss the point that such outcomes may actually be evidence of closely matched groups, and that the excessive bluffing involved in such warfare may be part of the estimates by each group of the other's strength. If such were the case, then even single killings might be extremely important in shifting the balance, and one might expect that significantly weakened groups would avoid battle and sometimes join forces with other groups even when great risk or sacrifice was involved. Both kinds of behaviour have been reported in primitive societies.

When the weapons of a species are restricted in their versatility, stereotyped responses may effectively prevent damage, and, as a result, one may see what looks like a ritualized or sham battle—even a comically specialized one. Again, I suggest that we are probably always seeing, in such cases, exceedingly well-matched opponents rather than sham battles, and that observers might learn this very quickly if they could be suddenly cast into the skin of one of the combatants and had to dream up their own responses.

Matthews (in Carthy and Ebling, 1964) suggests that chimpanzees are not highly aggressive, as is indicated by the tolerance of the presence of subordinates by the dominant, so long as he

is given first choice of females and food (and, one presumes, sleeping spots!). Assuming that Matthews is correct (however, see Lawick-Goodall, 1968), one wonders what else a dominant chimpanzee might gain from his position. Others have suggested that gorillas, with all their size and strength, are always peaceful, yet Dart (1961) reported a death battle between two dominant males of adjacent bands.

That ritualization and threat can be effective in establishing and maintaining dominance without injuries or death is evidence only that both inhibition of aggression and aggression are subject to natural selection. Aggressive interactions are also crucial when they are conducted by threats: but acceptance of appeasement signals by a dominant can only evolve if it benefits the dominant, just as appeasement, or giving in, can only evolve when, on the average, the subordinate also gains by giving in. As commodities become less and less available, less advantage is realizable from giving up.

In weighing the possibilities of gain or loss in aggression, degrees of desperateness can be involved in extremely complex fashions, just as probabilities more or less directly linked with actual reproduction, as I have suggested above (see Hamilton, 1963, 1964a, b; Laek, 1966; Williams, 1966b), can be 'weighed' in extremely complex fashions.

Complex or all-out appeasement, such as may be the case in exposure of vulnerable regions at close ranges by a subordinate, probably could be successful only if there had been a long history of appeasement (Lorenz's often-quoted example of exposure of the jugular vein region by subordinates is doubted for wolves and dogs on apparently firm grounds by both Schenkel, 1967, and Scott, 1967; evidently, it is the dominant which displays this behaviour). Appeasement may arise from (1) successfully confusing an opponent into a parental or male-female response or (2) gradual reduction and change from minimally effective retreating. Rudimentary appeasement may be no more than departure from the vicinity of the other individual's food, mate, offspring, or territory. A dominant animal might give up the chase early because it will be unprofitable, either because it yields no further gain, and may yield loss if further combat ensues, or because it renders the defended objects or space more vulnerable to other potential usurpers.

By the various arguments I have given, what appears to be or is presumed to be altruistic behaviour should evolve only in one or another, or some combination, of four contexts: (1) care of offspring, (2) care of mate, (3) gaining and



maintenance of approval and status in groups within which one must operate to live and reproduce, and (4) maintenance of such groups. Tolerance or appeasement in aggressive interactions should fit roughly the same pattern.

In keeping with the suggestion that man is reproductively selfish and that all other functions are subsidiary to reproduction, I would argue that if anything approaches being inevitable in him, it is not aggression but the taking of gain. The best hypothesis seems to be that aggression is neither an inevitable instinct, nor solely associated with tension or frustration or overpopulation. It is probably best interpreted as a behaviour that may be expected to occur whenever it is likely to lead to gain that, in terms of man's history, can be translated as having potential reproductive value.

Regardless how pessimistic it may seem at this moment, so far as I can see, the only apparent way to prevent wars is to develop and maintain situations in which each potential participant remains convinced that he cannot gain by war. In this light, one cannot be happy at the prospect of the development of defenses against nuclear weapons, which may be the only reason we have not recently been involved in major wars. This position supports arguments for the urgency of an international peace-keeping agency, and it suggests that an effective one will not be organized until the powerful nations are all convinced it is in their own best interests.

### GROUP-LIVING AND WAR

When animals live in groups by necessity, then we ought to expect relative intragroup peacefulness because dominants gain from not hurting subordinates or exiling them from the group. Appeasement, therefore, should be more complex in animals which live in groups.

Perhaps it is importantly related to his evolutionary history of living in groups that modern man seems perplexed because while he is doing what, individually, seems appealing, right, moral, appropriate, reasonable, enjoyable, and peaceful, groups of men nevertheless carry out actions that he, individually, abhors—partly because they seem to endanger him or inconvenience him or his family.

Primitive men lived in co-operative bands, apparently for the past two million years at least; on this point there seems to be no disagreement. Living in groups larger than the smallest reproductive units, however, inevitably involves certain disadvantages. The most important of these seem to be increased competition for all commodities and greater likelihood of disease and parasite

transmission. Why, then, should animals live in groups—that is, groups larger than the smallest reproductive unit, say, a single male and his female or females and their offspring?

I believe that only three reasons can be advanced to explain animals living in tightly knit groups: (1) susceptibility to predation is lowered either because of aggressive group defence, as in savannah baboons, or because of the opportunity of causing some other individual to be more available to predators, as in schooling fish and herds of small ungulates; (2) the nature of prey prevents individuals or families from securing enough food to make splintering off profitable, as in wolves in certain regions; or (3) there is a shortage of space for some essential function, such as breeding sites of some marine birds and mammals. Of course, more than one of these functions may be involved in any particular case of group-living; one suspects that some penguins, for example, might profit both in food location and in escaping from predators by staying in groups as they move about in the ocean, and the clustering of their nests and young may likewise be advantageous both because of predators and because of shortages of nesting sites that are maximally suitable for other reasons.

In any case, in the absence of one or more of these three kinds of advantages, group living has to be detrimental because it reduces the individual's chances of using his own peculiar abilities to out-reproduce his neighbours.

The almost universal explanation for group-living in man is that he profited from hunting game too large for single men to kill easily (Washburn, 1959; Washburn and Jay, 1968; Hockett and Aseher, 1964). The evidence is that fossil tools, weapons, and bones indicate that man has hunted large game for perhaps the past two million years, and that agriculture did not exist on a very broad scale until a few thousand years ago. The general enthusiasm with which modern men hunt, and co-operate in hunting, the tendency of men to group, and the ease with which children learn to hunt and kill game, have also been used as supporting evidence.

This is a most important argument, for, indeed, the adaptive significance of group-hunting is most often given as the selective context in which man became a man, by which his brain size tripled across two million years and he acquired his present intelligence and his other peculiarly human traits. So long as this is true, this idea is the most significant one that can be mentioned regarding man's history. It would seem that nothing could be more important for our understanding of man than the presence of an alternative more likely

than this one. Yet I believe that such an alternative exists.

Essentially the same kinds of evidence as given above indicate that man has been a warring, cannibalistic animal during the same lengthy period—when he was, in fact, becoming a man—and during all agricultural periods as well and even perpetually in regions where group-hunting was never practised and big game was never available and food shortages were unknown. Furthermore, man himself is a more demanding protagonist or prey than any other kind of animal; the selective effect of direct warfare, as I have indicated, would be more direct and a better explanation of very rapid evolutionary change; and war seems to crystallize co-operative efforts more dramatically and effectively than any other human activity. Not only is there no upper limit on effective group sizes in war, as in hunting groups, but there should have been continual pressure to increase group sizes, particularly as technology advanced means of conducting warfare and increased intelligence made massive co-operative effects possible. In contrast, if hunting had remained the chief context of group-living, group size should have gone down with increasingly effective weaponry and predatory strategies.

I suggest that, at an early stage, predators became chiefly responsible for forcing men to live in groups, and that those predators were not other species but larger, stronger groups of men. Once men began to function in groups, even if only to hunt big game at first, there is every reason to suppose that they would have used their collective ability to make it impossible for individual men to reproduce outside groups. This kind of situation has apparently prevailed every time modern men accustomed to living apart with their families in agricultural societies have tried to establish themselves in new lands already peopled with humans living in hunting-gathering bands, or lacking in sufficient population and law to prevent predatory bands from forming and persisting out of their own ranks.

Intraspecific aggression exists on two levels when animals are forced to live and interact in groups. I would speculate that killing and, to a much lesser degree, cannibalism, have for a very long time been man's chief mode of reproductive competition at the inter-group level; and the two kinds of competition that fall short of killing more prevalent within groups. I do not believe that the kind of mild and largely indirect competition central to the hypothesis that man evolved intelligence because it enabled him to hunt better can easily be used to explain the rapid evolutionary change in men living in bands, and least of all

man's divergence so far from his closest living relatives.

To relate and contrast this view to those prominently advanced recently to account for man, I would note that it emphasizes intraspecific rather than interspecific competition (cf. Brown, 1958; Schaffer, 1968). It suggests that the most important 'environmental change' (cf. Robinson, 1963) was the development of culture, not, however, chiefly as a better means of hunting (cf. Dobzhansky and Montagu, 1947; Hockett and Ascher, 1964; Bartholomew and Birdsall, 1953; Washburn, 1959; and most others), but chiefly as a better means of warfare. Finally, it suggests that war was the chief vehicle of intergroup selection, and that intergroup selection was more important, as compared to intragroup selection, than has generally been considered the case. Others, such as Freeman (1964), Emlen (1966), and Ardrey (1966), have already argued that war has played a significant role in human evolution: the particular role suggested here has previously been advocated by Alexander and Tinkle (1968) and Alexander (1969).

One question remains from the three posed earlier concerning explanations for evolutionary changes in man's brain size: Why did the brain apparently stop increasing in size, or the trend even reverse itself, a few thousand generations ago? Assuming for the moment that this is not a false question, to answer it one may ask, first, how selection is apparently affecting brain functions such as variations in intelligence (as measured by scores on intelligence tests) today. The answer, regardless of the present direction of change, must be given not only in terms of intragroup selection—relative family sizes, child mortalities, and percentage of successful marriages (and of, especially, paternity *per se*)—but also in terms of the effects of war or intergroup strife. Except for particular cases in which variations in family size and child mortality might be characteristic of populations that are genetically different in regard to brain function, war seems to have reached a technological stage, and the powerful nations have become so genetically mixed and in many cases alike, that war can scarcely be affecting man's genetic makeup in a very consistent fashion (see also Livingstone, 1967). There are some fairly recent (though small-scale) examples to the contrary, such as total annihilation of the Tasmanian natives by Europeans. In no such case, however, do we have good reasons to believe that significant changes, either way, have been brought about in the brain function of man as a whole.

The situation postulated earlier for primitive man, in which warfare is argued to be chiefly re-



sponsible for increases in brain size, is quite different. It calls for war to be waged in some relationship to degrees of genetic difference and raises the question of the selective value and background of assisting one's closer relatives at the expense of non-relatives or distant relatives. In any species engaging in the more violent kinds of intraspecific competition, ability to recognize and spare close relatives would be highly favoured. Such an effect, moreover, would have been facilitated by man's tendency to live in small bands or family groups. Members of one's own band could automatically be treated as relatives, or tolerated and even assisted; those of other bands could equally automatically be treated as competitors or the enemy. Man is aware, to an extraordinary degree, of differences in his relationship to the other men with whom he lives. In some modern hunting-gathering peoples still living in small groups, and in which intertribal aggression is prevalent, the extent and nature of such knowledge has amazed anthropologists more than any of their other attributes. Part, but perhaps not all, of the value of such knowledge has surely been related to outbreeding; despite continuing denials of this function (Farb, 1968, Livingstone, 1969), the extensive knowledge of genetic relationships and stringent marriage laws that exist in small, isolated groups of highly uniform (and evidently inbred) people such as some Australian aborigines (Radeliffe-Brown, 1951) strongly support this argument (see also Fox, 1967a). Livingstone uses an evolutionarily unlikely 'group selection' hypothesis of the sort criticized above to support his rejection of a deleterious inbreeding hypothesis for incest. Both he and Farb (and many others) imply that because incest (as a consciously applied rule) is cultural, it cannot be related to a history of genetic selection. Livingstone's argument is that extreme inbreeding was favoured in early hominids because it decreased the frequencies of genes deleterious in the homozygous condition. He admits that such changes would 'take a rather long time in some cases', and (later, in discussing small gorilla bands) that 'even a very small amount of gene flow would counteract this trend toward complete homozygosity...'. The long time required and easy counteracting by outbreeding seriously detract from his argument, for any individuals successfully outbreeding would be favoured by their avoidance of deleterious homozygosity. My arguments in this paper support an hypothesis opposite to his: that long-persisting and essentially universal cultural practices such as incest avoidance are most likely

to be reinforcers of previous trends in genetic selection.

## CONCLUDING REMARKS

Approaches to the question 'What is man?' and 'What do we do about it?' include, as I have already indicated, studies of fossils, of primate biology, and of living men. All of these approaches are being pursued more effectively now than ever before, and attempts at synthesis are becoming more frequent and more convincing (Freeman, 1964; Emlen, 1966; Howell, 1967; Fox, 1967b; Lancaster, 1968; Tinbergen, 1968; and many others). General understanding of the evolutionary process influences not only how the results of all investigations of man are interpreted but, probably more importantly, how they are selected and prosecuted in the first place. The potential profoundness of this influence can be appreciated by examining the papers published across the past two decades in any major anthropological journal, such as the *American Anthropologist*.

Nevertheless, we have scarcely begun to examine man in this light, partly because not everyone who is aware of evolution, and willing to accept it, understands it, and partly because only a tiny fragment of the world's population has yet become involved in what I shall term this 'major philosophical revolution'. The list of human activities that deserve to be reviewed and investigated further with this kind of insight is indefinitely long. One could mention the nature of sexual dimorphism and its patterns, in behaviour as well as morphology, throughout life; the significance of menopause; the appropriateness of various attitudes toward pre-marital and extra-marital sex; monogamous and polygamous tendencies in the two sexes and under different conditions; the significance of relationships between revolution-minded youth and the 'power structure' under different conditions of stress and affluence; the genesis and maintenance of inter-group hostilities and war; the nature and significance of genetic variations among the peoples of the world; and educational systems, social systems, penal codes, city planning, and international politics. No activity of man is exempt. Furthermore, it will not do to leave the questions of how man's evolutionary background bears on these problems to a few individuals. Evolution is no longer the property of a small group of biologists: to understand it thoroughly has become the responsibility of every person with a potential role in man's future.

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Robert S. Bigelow's 1969 book, *The Dawn Warriors* (Little-Brown, Boston) was published just before this manuscript was submitted, but I did not learn this until several months later. Although Bigelow and I published together on another topic in 1960, we did not become aware until 1968 of our common interest in the present topic. Our similar arguments were derived independently.

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# THE VEGETATION OF CLIFFY ISLAND, VICTORIA, AUSTRALIA

By G. S. HOPE† and G. K. THOMSON\*

**ABSTRACT:** 41 Vascular plant species, 8 bryophyte species and 10 lichens have been found at Clifty Island which lies about 12 miles E. of Wilsons Promontory. Nearly half of the vascular plants are aliens, a much higher proportion than is known for other Bass Strait islands, and this is due to the presence of a manned light station on the island. Six plant communities are described and mapped and species lists given for each. The *Poa poiformis* closed tussock grassland is discussed in the light of previous work and is regarded as a climax community of some small islands.

## INTRODUCTION

Clifty Island is the easternmost island in the Seal or Discovery Group which consists of five granite islands lying about 12 miles E. of Wilsons Promontory and about 15 miles S. of Port Albert. Sealers visited Clifty Island during the period 1800-1920, but no permanent dwellings were established until 1884 when the light station was erected. At present this consists of three houses, a radio shed, a foghorn shed and the lighthouse. Stores are landed at the north of the island and brought to the station by a cable trolley. Rubbish and sewage are dumped over the cliffs but waste water is allowed to drain onto the NW. slope. Soon after the station was established goats were introduced onto Seal Island about 2 miles N. of Clifty Island, to act as an emergency food supply, and descendants of these animals are still running wild. According to lighthouse staff, however, no grazing animals have ever been introduced to Clifty Island. There are no records of any fires on the island.

A plant census with brief notes on the island was published by Gillham (1961) as part of her investigation into possible relationships between sea birds and vegetation on several Promontory islands. Further information on the vegetation of the island was required for a study of pollen deposition being undertaken by one of us (GSH) on this and nearby areas. The vegetation was studied in May and November 1967 during field trips to service the pollen trap set on the western side of the island. Fig. 1 includes a sketch map of the island with approximate contours and

boundaries of the plant communities. Although these boundaries are estimated, some control of the mapping was obtained from small scale aerial photographs. The scale was derived from 'Sailing Directions for Victoria including Bass Strait' (1959) which records the dimensions as 400 yd E.-W., 300 yd N.-S. and the maximum height as 142 ft. These indicate that the island is about 35 acres in area; the area of 100 acres given by Gillham (1961) is apparently in error while the height of 180 ft she recorded refers to the elevation of the top of the lighthouse.

## GEOMORPHOLOGY AND CLIMATE

The island is a humped granite mass with sheer cliffs up to 100 ft in height on the southern and eastern sides. To the NW. the land slopes gently into the sea. Much of the granite is fairly coarse-grained and similar to that found on parts of Wilsons Promontory, but dikes of fine grained granite and zones of contortion and jointing are frequent. A cleft which is only 6 ft wide but over 60 ft deep has formed in one of these zones. This cleft intersects the coast at the eastern end of the island and a small boulder beach occurs there. This is the only area on the coast not swept clear of detritus by wave action. The weathering of numerous joint cracks gives an irregular surface to the cliff tops and the lower NW. slopes, but the remainder of the surface is smooth and rounded, with a little gravelly sand forming a soil between bare granite sheets and boulders.

The coast is exposed to swell from the SW. to NE. and the deep water (20 fathoms) around

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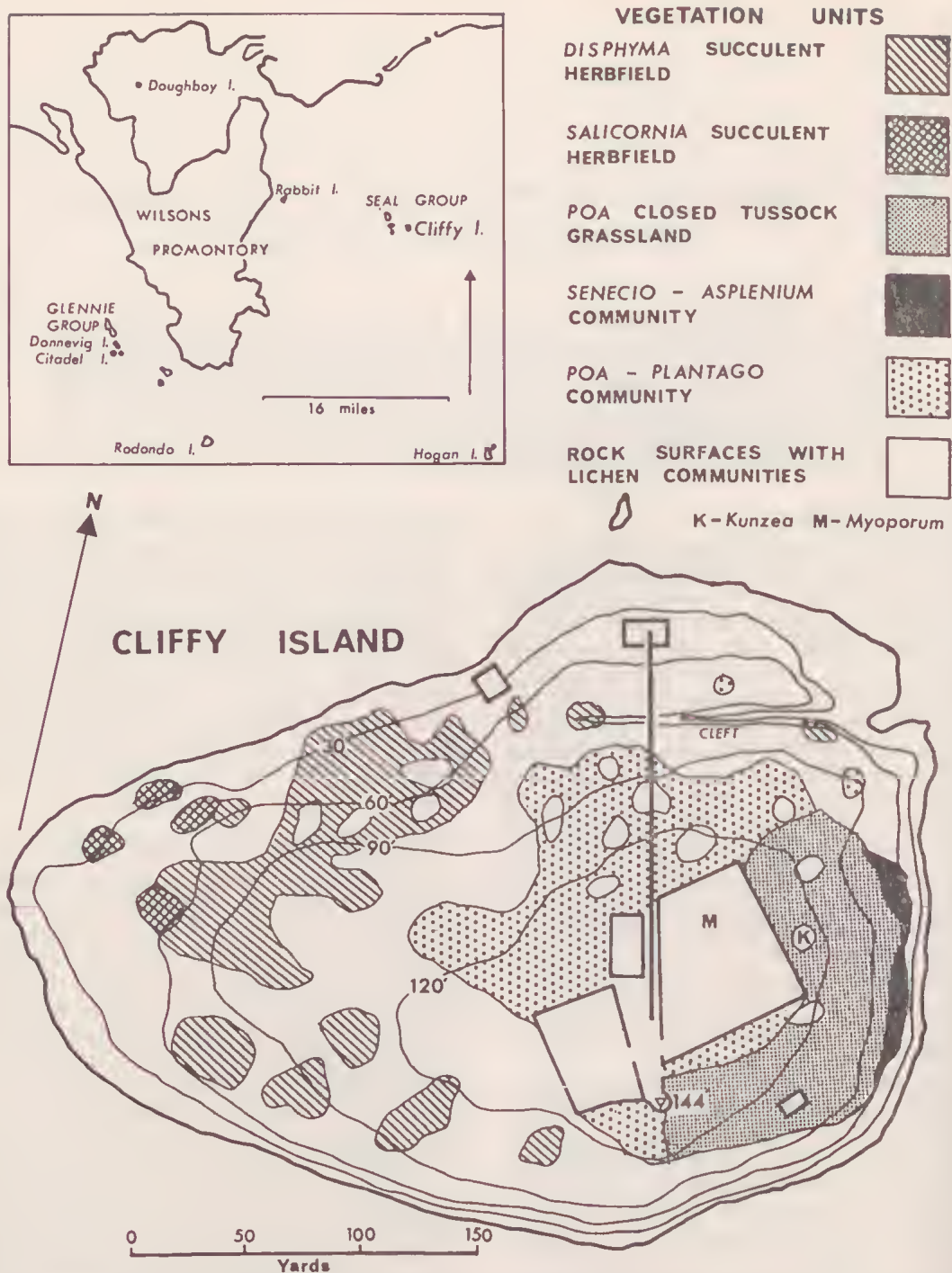


FIG. 1—Distribution of vegetation on Cliffy Island. Inset shows the location of some of the islands mentioned in the text.



Cliffy Island allows direct wave attack on the cliffs. During storms in which wave and wind directions (mainly E. or SW.) coincide, spray falls over the whole island. Conditions at Cliffy Island are probably similar to those of the Wilsons Promontory lighthouse (inset, Fig. 1), which is the nearest station at which weather records are kept. The annual precipitation there is about 41 in. and strong winds from the W. and E. are common. However, unlike Cliffy Island, this station is sheltered from the N. and subject to an orographic increase in precipitation, so that rainfall on Cliffy Island is probably intermediate between the Promontory figure and the annual mean for Port Albert which is 28 in.

## FLORISTICS

The census of vascular plants, bryophytes and lichens in Appendix 1 includes the records of Gillham. The list of 10 lichen species is probably incomplete. Those found are all fairly common colonists of bare rock surfaces. It is interesting that *Caloplaca murorum* (Hoffm.) Th. Fr. is missing from the list, for this lichen forms a characteristic orange zone on rocks exposed to salt spray in Tasmania and the Tasmanian Bass Strait islands. Although the species has been reported in Victoria, the most northern point at which this zone has been noted is at Hogan Island which lies 30 miles S. of Cliffy Island.

Eight moss species are recorded but no liverworts, and with the exception of *Bryum microerythrocarpum* these mosses are apparently all of wide occurrence on the smaller Bass Strait islands. *Bryum microerythrocarpum* is a recent segregate from the *B. chrysoneuron* C. Muell. complex, and is known from only two collections in SE. Victoria. F. von Mueller collected *B. chrysoneuron* from Wilsons Promontory in 1850 (J. H. Willis, pers. comm.) and undoubted *B. microerythrocarpum* has been found there recently by one of us (GKT). Although the only previous record of *Barbula australasiae* is from Big Green Island in the Furneaux Group (Norman 1966) it is probably common but is readily overlooked due to its small size and resemblance, when sterile, to other small mosses. Gillham (1961) has recorded *Campylopus introflexus* (Hedw.) Brid. on three granite islands, Citadel, Dannevig and McHugh, and it is curious that it was not found on Cliffy Island which is of similar size.

Of the 41 vascular species only three are not herbs. One is the only fern species, *Asplenium obtusatum*, which occurs as a robust succulent maritime form around the cliff tops. Two shrub species, *Myoporum insulare* and *Kunzea ambigua* are present, as single specimens only, in the shel-

ter of walls and buildings. The best represented family is the Poaceae with eleven species including the tussock-forming grass *Poa poiformis* which is characteristic of the Bass Strait islands, although it occurs in coastal areas as well. Other species commonly found on the islands include *Pelargonium australe*, *Apium prostratum* (as the robust form), *Lavatera plebeia*, *Disphyma australe*, and *Bulbine semibarbata*. Records for the genus (*Bulbine*) may be inadequate. Both *B. semibarbata* and *B. bulbosa* are common on Wilsons Promontory (Ewart 1909). Gillham (1961) however recorded only *B. semibarbata* from the islands that she visited and Norman (1967) recorded only *B. bulbosa* from Rabbit Island. (See inset Fig. 1 for location). Since both species are superficially similar and occupy similar habitats, it is probable that both species occur throughout the islands and that further collections are required. On any one island, however, one or other species may predominate.

Eighteen of the forty-one herbaceous species are aliens. These include nine of the grass species and three composites. This is a much higher proportion than that recorded for other islands around Wilsons Promontory by Gillham (1961) or Norman (1967). On some islands further to the south where some grazing has taken place one third of the vascular flora may be made up by aliens, as at Hogan Island and at Big Green Island (Norman 1966).

Gillham (1961) compared eight islands around Wilsons Promontory on the basis of their ratios of species numbers to acreage. She also ranked the islands with a subjective estimate of their exposures, presumably based on their distance from other land and shelter from wave attack, and found a fair correlation between high exposure and a low species to acreage ratio. The ratio for Cliffy Island appeared anomalously high when compared with that of Rabbit Island which lies in a much less exposed position close to Wilsons Promontory. The ratios are of limited use (except where the islands compared are similar in size, geology and general location, as in this case) but the correlation with exposure can be improved if the native species only are considered. The ratios in Table 1 were derived by using all species (after Gillham 1961), and with native species only (using new records by Norman, 1967, for Rab-

TABLE 1  
APPROXIMATE SPECIES TO ACREAGE RATIOS

Island	Acreage	All Species	Native Species
Citadel	70	1 : 8	1 : 8
Dannevig	80	1 : 4	1 : 4
Cliffy	35	1 : 1	1 : 2
Rabbit	90	1 : 2.5	1 : 3
Doughboy	10	8 : 1	5.5 : 1



bit Island), and the islands are ranked in the order of exposure suggested by Gillham.

Cliffy Island has been preferentially enriched with alien species because of greater opportunities for introduction and the creation of new niches (increased water and protection by walls). This has marked effect on the species to acreage ratios, and the ratio calculated with native species gives the best correlation only with an estimate of exposure.

## VEGETATION

Six vegetation communities have been mapped on Cliffy Island and their boundaries are shown in Fig. 1.

- (a) *Disphyma australe* Succulent Herbfield
- (b) *Salicornia quinqueflora* Succulent Herbfield
- (c) *Poa poiformis* Closed Tussock Grassland
- (d) *Senecio lautus*—*Asplenium obtusatum* Community
- (e) *Plantago coronopifolia*—*Poa poiformis* Community
- (f) Rock Surfaces with Open Lichen Colonies (indicated by blank area on map).

In classifying and mapping coastal vegetation units such as these, the established definitions of structural forms by e.g. Beadle and Costin (1952), Wood and Williams (1960) are insufficient, and the terms used here require further explanation. Most authors use the term 'herbfield' in the context of 'Alpine herbfield', but the definition 'a closed community dominated by perennial herbs, including forbs and grasses' is appropriate for non-alpine communities. In the case of Cliffy Island, such herbfields are dominated by succulent-leaved herbs and the term 'succulent herbfield' has been used. The tussock grassland found on Cliffy Island fits structurally into the category of 'wet tussock grassland' of Beadle and Costin, but does not occupy the habitat defined for this form. The term 'closed tussock grassland' has thus been used, as it carries no environmental implications. The last three of the communities listed above have not been classified structurally as they are variable internally and do not appear to coincide with any established definitions. In the descriptions which follow the projective cover and species frequencies have been estimated and are not quantitative measures.

### (a)

#### *Disphyma australe* SUCCULENT HERBFIELD

*Disphyma australe* forms a close sward of vertical succulent leaves arising from branching ground-hugging stems. The height varies from 1–15 cm and the cover varies with the luxuriance of growth. The main occurrence is on the W. and

NW. slopes from 10 ft above sea level to 120 ft, though the best development occurs below 80 ft. Above 50 ft a few associated species including *Lobelia alata*, *Sonchus oleraceus* and *Hypochoeris radicata* become conspicuous. As noted by Gillham, the *Disphyma australe* is red and stunted in sites exposed to the S. and E. and robust where it occurs in sites sheltered from the wind on the W. and N. aspects. The herbfield is associated with extremely shallow soils on well drained slopes and covers many areas of rock too steep to retain soil. On the steep eastern cliffs, areas of vertical sward give way to isolated stands of *D. australe* in the *Senecio-Asplenium* community at the cliff top. Elsewhere the boundaries are distinct.

### (b)

#### *Salicornia quinqueflora* SUCCULENT HERBFIELD

This herbfield is similar in structure to the *Disphyma* succulent herbfield although the sward is made from succulent photosynthetic stems which arise from stolons. The herbfield is restricted to a few small areas on the western side of the island within 35 ft of sea level. Here the spray collects in hollows on a gentle slope and *Salicornia quinqueflora* has colonised these shallow pools and drainage runnels. There appear to be no associated species in the herbfield and the boundary between the *Disphyma australe* on the well-drained slopes and the *Salicornia quinqueflora* is distinct.

### (c)

#### *Poa poiformis* CLOSED TUSOCK GRASSLAND

*Poa poiformis* is a tough tussock forming grass giving a grassland of separated tussock bases and densely interlacing erect leaves. The tussock bases are usually 40 cm in diameter and spaced 20–40 cm apart and the grassland may be up to 1 m high, although it is usually from 30 cm to 60 cm. This grassland is restricted as a closed community to the south eastern area of the summit of the island on gentle slopes, from 90 to 130 ft above sea level. The soil attains a maximum depth over this area, with organic rich sands and sandy loams reaching an average depth of 20 cm, but boulders and surface outcrops are still common. A small colony of mutton birds nest in the area and these birds have burrowed into the bases of the tussocks, trampled pathways through the grass, and presumably 'enriched' the soil with their droppings.

Within the closed tussock grassland other vascular species are rare but include *Pelargonium australe* and *Hypochoeris radicata*. All eight species of moss were recorded from the area, either in moist areas between the tussock bases or bare areas next to rock sheets and boulders where

drainage from the summit would be concentrated. *Thuidium furfurosum* is occasional in a somewhat stunted form among the tussocks. *Sematophyllum homomallum* is very rare, and restricted to this grassland, although it is a fairly common coloniser of the edges of granite rock sheets on Hogan Island and Wilsons Promontory. At the boundaries of the community, the tussocks are reduced in size and separated by bare ground. Some of the introduced grass species and *Plantago coronopus* occur here.

(d)

*Senecio lautus*—*Asplenium obtusatum* COMMUNITY

A robust succulent form of *Senecio lautus* and the fern *Asplenium obtusatum* are associated with occasional *Poa poiformis* tussocks and plants of *Disphyma australe* along the cliff tops of the eastern side of the island. The community may represent an ecotonal change from *Disphyma* succulent herbfield to closed tussock grassland. The community is restricted to the jointing cracks with relatively deep soil where there is some shelter. *Apium prostratum*, *Bulbine semibarbata* and several species of introduced grasses are also present in the community which is very variable structurally, with a wide range of cover and local stands dominated by *Senecio lautus*, grasses or *Disphyma australe*.

(e)

*Plantago coronopus*—*Poa poiformis* COMMUNITY

This community, which occurs on the northern area of the summit, approaches an open to very open tussock grassland in structure, with occasional *Poa poiformis* tussocks up to 20 cm in height. However, *Plantago coronopus* is very frequent and it has a greater cover in the community than does the *Poa poiformis*. Much of the area is occupied by isolated plants with the grasses *Parapholis incurva* and *Hypchoeris radicata* as common sub-dominants. Most of the introduced plants occur in this community, generally in the shelter of walls or buildings or in the area where drainage water is released. The soils are very shallow and dry and there are large areas of bare rock. In some places *Spergularia media* and *Sagina apetala* have trapped soil particles and built up a few centimetres of soil around their stems and leaves, which remains even when the plants are dead. The boundaries of this community are zones a few metres wide in which the cover and frequency of *Plantago coronopus* varies so that the change from closed tussock grassland is indistinct.

(f)

ROCK SURFACES WITH OPEN LICHEN COLONIES

Only the main areas of rock are shown by the blank zones on Fig. 1; in addition to these, scat-

tered patches of rock occur in all the other communities. Most rock surfaces from 6 ft above sea level on the NW. aspect and from 40 ft on the southern and eastern aspects have lichen cover. The characteristic red *Caloplaca cinnabarina* occurs in the lowest zone where saltspray is intense. Other crustose lichens including *Buellia* sp. *Lecidea* sp., and *Lecanora* sp. are found above the *Caloplaca* zone. On rocks higher than 60 ft above sea level foliose lichens become abundant. *Parmelia* sp. cf. *conspersa* and the orange *Xanthoria ectanea* both grow luxuriantly, the latter sometimes in association with another orange fruiticose species, *Teloschistes spinosus*. The crustose *Caloplaca elegans* and a further *Parmelia* species are found on the summit area of the island.

## DISCUSSION

The extensive occurrence of *Poa poiformis* tussock grassland on some islands of Bass Strait has been regarded by some authors as a post-European settlement phenomenon. Guiler (1967) studied original surveys of islands in the Furneaux Group and concluded that on many of the smaller islands tussock grassland had replaced an extensive shrubland following burning, clearing and the introduction of rabbits. Norman (1967) gave evidence of an extensive shrub cover on the sheltered side of Rabbit Island and suggested that the tussock grass community, at present covering most of the island, was formerly restricted to a coastal belt. The shrubs were removed by fire and regeneration prevented by rabbits. Norman cited the case of Rodondo Island (inset Fig. 1) as an example of shrub and woodland development in the absence of fires (Bechervaise 1947). However this island is over 1000 ft high and shrub species do not occur in the salt spray zone below 300 ft so that it cannot be compared with Rabbit Island which attains only 194 ft. Islands comparable to Rodondo Island, such as Curtis Island and Deal Island also have extensive shrublands, despite frequent fires. As previously noted, the species to acreage ratio for Rabbit Island does not demonstrate that any great depletion of species has occurred there and it is possible that tussock grassland has always dominated the exposed (south eastern) side.

Gillham (1962) suggested that the occurrence of *Poa poiformis* tussock grassland is due to its tolerance of both salt spray and trampling by sea birds which could prevent shrub or heath species from colonising. These two factors are complementary; in sheltered areas trampling and guano deposition would have to be heavy to prevent a shrub overstorey from developing while in very exposed areas these disturbances might lead to a



breaking up of the closed grassland with consequent erosion. Gillham also suggested that guano may be necessary for the maintenance of healthy grassland. One problem with this view of *Poa poiiformis* closed tussock grassland as sea-bird dependent is that on many islands areas of grassland may be found without associated rookeries. Gillham (1962) has suggested that these areas may have been the sites for older rookeries.

It seems likely that Cliffy Island has supported tussock grassland for a long time. Of the shrubs on the island the *Myoporum insulare* has been introduced, and it is possible that the *Kunzea ambigua* has also been deliberately planted, as it is known that plants have been exchanged by the light keepers at Wilsons Promontory and Cliffy Island. At present there are no signs of regeneration nor of traces of older plants, so that if native, it may have grown from seed from Wilsons Promontory, reaching one of the few sites favourable for its establishment on the island. The other islands in the Seal Group appear to be equally unsuitable for shrubs. No shrubs could be detected on the aerial photographs and none could be seen when the islands were inspected by field glasses from a boat close to their shores.

These islands, unlike Cliffy Island, appear to carry closed tussock grassland over most of their surfaces and no areas similar to the *Poa-Plantago* community were seen. This suggests that this community may be a recent development on Cliffy Island and result from burning and trampling of closed tussock grassland, followed by soil erosion around the light station and the invasion by introduced species. The rookery covers only part of the closed tussock grassland area today but may have been more extensive in the past. The introduced grasses have not formed a closed grassland.

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## APPENDIX:

### PLANT SPECIES OCCURRING IN EACH OF THE COMMUNITIES

#### KEY

- 1—*Disphyma australe* succulent herbfield
- 2—*Salicornia quinqueflora* succulent herbfield
- 3—*Poa poiiformis* closed tussock grassland
- 4—*Senecio laetus*—*Asplenium obtusatum* community
- 5—*Poa poiiformis*—*Plantago coronopus* community
- 6—Bare rock areas with open lichen colonies.
- \*—Introduced species
- †—not recorded by Gillham (1961)
- ‡—not recorded by the authors.

#### SPECIES

1 2 3 4 5 6

#### Lichens (†)

<i>Buellia</i> sp.						+
<i>Caloplaca cinnabarina</i> (Ach.) Zahlbr.						+
<i>Caloplaca elegans</i> (Link) Ach.						+
<i>Lecanora</i> sp.						+
<i>Lecidea</i> sp.						+
<i>Parmelia</i> sp. cf. <i>conspersa</i>						+
<i>Parmelia</i> sp.						+
<i>Teloschistes spinosus</i> (Hook. f. & Tayl.) J. Murray						+
<i>Xanthoria ectanea</i> (Ach.) Räs. ex R. Filson						+

#### Bryophytes

† <i>Barbula australasiae</i> (Hook. et Grev.) Brid.				+		+
† <i>Bryum argenteum</i> Hedw.				+		+
<i>B. billardieri</i> Schwaegr.				+		+
† <i>B. capillare</i> Hedw.				+		
† <i>B. microerythrocarpum</i> C. Muell. et Kindb.					+	
† <i>Sematophyllum homomallum</i> (Hamp.) Broth.						+



SPECIES	1	2	3	4	5	6	SPECIES	1	2	3	4	5	6
† <i>Thuidium furfurosus</i> (Hook. f. et Wils.) Jaeg.			+				FUMARIACEAE						
† <i>Tortella calycina</i> (Schwaegr.) Dix.			+				† <i>Fumaria officianalis</i> L.						
<i>Tortula princeps</i> De Not			+		+		GERANIACEAE						
Vascular Plants							<i>Pelargonium australe</i> Willd.			+	+	+	
ASPLENIACEAE							JUNCACEAE						
<i>Asplenium obtusatum</i> Forst. f.				+			† <i>Juncus bufonius</i> L.						
AIZOACEAE							LILIACEAE						
<i>Disphyma australe</i> (Ait.) N. E. Brown	+			+	+		<i>Bulbine semibarbata</i> (R. Br.) Haw.					+	+
APIACEAE							MALVACEAE						
<i>Apium prostratum</i> Labill. ex. Vent. (= <i>A. australe</i> )				+			<i>Lavatera plebeia</i> Sims					+	+
ASTERACEAE							* <i>Malva parviflora</i> L.						+
<i>Cotula coronopifolia</i> L.	+				+		MYOPORACEAE						
<i>Gnaphalium candidissimum</i> Lam.					+		† <i>Myoporum insulare</i> R. Br. (cultivated)						
<i>G. luteoalbum</i> L.					+		MYRTACEAE						
* <i>Hypochoeris radicata</i> L.			+	+	+		<i>Kunzea ambigua</i> (Sm.) Druce						+
<i>Senecio</i> aff. <i>lautus</i> Forst f. ex Willd.					+	+	PLANTAGINACEAE						
†* <i>Sonchus asper</i> (L.) Hill					+		* <i>Plantago coronopus</i> L.				+		+
* <i>S. oleraceus</i> L.	+				+		POACEAE						
CAMPANULACEAE							* <i>Bromus diandrus</i> Roth.					+	+
<i>Lobelia alata</i> Labill.	+						* <i>B. mollis</i> L.				+		+
CARYOPHYLLACEAE							†* <i>B. unioides</i> H.B.K.					+	+
<i>Polycarpon tetraphyllum</i> (L.) L.					+		<i>Cynodon dactylon</i> (L.) Pers.					+	+
* <i>Sagina apetala</i> Ard.					+		* <i>Hordeum leporinum</i> Link.				+		+
<i>Spergularia media</i> (L.) Presl.					+		* <i>Lagarus ovatus</i> L.					+	+
CHENOPODIACEAE							* <i>Lolium perenne</i> L.					+	+
* <i>Atriplex hastata</i> L.					+		* <i>Parapholus incurva</i> (L.) C. E. Hubbard					+	
<i>Salicornia quinqueflora</i> Bung. ex Ung. Sternb.	+						†* <i>Pennisetum clandestinum</i> Hochst. ex Chiov.						+
CRASSULACEAE							<i>Poa poliformis</i> (Labill.) Druce				+	+	+
<i>Crassula sieberiana</i> Ostenf.					+		* <i>Vulpia bromoides</i> (L.) S. F. Gray					+	+
							POLYGONACEAE						
							†* <i>Rumex crispus</i> L.						
							PORTULACACEAE						
							† <i>Calandrinia calyptata</i> Hook. f.					+	+
							PRIMULACEAE						
							* <i>Anagallis arvensis</i> L.						+



## REPRODUCTION AND ONTOGENY OF *GOMPHOCY THERE AUSTRALICA* HUSSAINY (CYTHERIDAE, OSTRACODA)

By S. U. HUSSAINY\*

**SUMMARY:** The reproduction and ontogeny of *Gomphocythere australica* were studied. The species is dioecious, with a sex ratio of 1:1. Reproduction is by syngamy only. Eggs are retained in the posterior end of the female carapace, only larvae of 2nd stage being released. There are nine developmental stages; the sequence of addition of appendages at each moult follows that described by Müller. The furca, however, becomes rudimentary at the fifth instar and in the adult is represented by two thin, juxtaposed lamellae. Appendages are added at each instar except the third.

### INTRODUCTION

Most published work on the life history and metamorphosis of Ostracoda appeared in the latter half of the nineteenth century and in the first two decades of this century; Kesling (1951) reviewed it. He also gave a detailed description of the morphology of the various moult stages of *Cypridopsis vidua* (O. F. Müller 1776) Brady 1867. More recently Theisen (1966) described life histories of seven species of Danish brackish water Ostracoda. Most studies seem to have been carried out on cyprid ostracods. Comparatively little is known of the development of freshwater Cytheridae.

The present paper records some observations on reproduction and compares the various instars during post-embryonic development of a cytherid, *Gomphocythere australica* Hussainy 1969.

### MATERIALS AND METHODS

Quantitative samples of sediments were collected from the littoral regions of Lake Purrumbete, Victoria, Australia, during July-September 1967. In the laboratory, samples were transferred to enamel trays and aerated. De-ionized water was used to make up the loss due to evaporation. Specimens appeared after about two or three days. The data obtained from field-collected material was supplemented with data from laboratory-cultured material. Cultures were maintained at 20°C  $\pm$  2°C in 'cavity blocks' using water and detritus from the culture trays.

Most of the observations on the development

were based on live material; however, material preserved in 70% alcohol was also used. For microscopic examination specimens were mounted in polyvinyl alcohol with chlorazol black. All sketches were made using a camera lucida.

### DISCUSSION

Ostracoda are dioecious and both parthenogenetic and syngamic reproduction is common among them. It appears that an alternation of parthenogenesis and syngamy does not occur (Ferguson 1944, Kesling 1951). With the known exception of *Darwinula stevensoni* Brady and Robertson (1870) many Myodocopida and several cytherid genera including *Gomphocythere*, all are oviparous (McGregor 1968, McKenzie and Hussainy 1968). Some species reproduce by parthenogenesis only; in *Cypridopsis vidua*, for example, the occurrence of males has never been established (Kesling 1956).

Males have been recorded for all species of *Gomphocythere*, and there is a distinct sexual dimorphism. Reproduction is by syngamy. Females are much larger than males and their shell is very swollen at its posterior region to form a roomy 'incubatory cavity' for the reception of ripe ova. The sex ratio appears to be almost 1:1 (2330 ♂ : 2010 ♀, during July-September 1967).

### COPULATION

Copulation in Ostracoda has been observed in several species, e.g. *Entocythere heterodonta* Rioja (Kaufman 1892) and *Potamocypris smaragdina* Vavra 1891 (Ferguson 1944). In the present in-

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vestigation, copulation was observed several times in the laboratory cultures and in field-collected material. The male attached itself to the dorso-posterior region of the female shell and held securely thereto by means of its second antenna. The ventral cavity of the male was kept open by the long curved claw of the 2nd thoracic appendage which was used as a wedge. The copulatory organ of the male was rotated and then inserted between the valves of the female shell.

#### BROODCARE

Among Cytheridae, broodcare is known or suspected for several marine or euryhaline genera, but *G. australica* Hussainy 1969 is the first species among freshwater Cytheridae for which it has been recorded (McKenzie and Hussainy 1968).

Larvae hatch out and undergo two moults while they are still within the female carapace. Only 2nd instar larvae are released. *Gomphocythere australica* may be unique among freshwater forms in being the only freshwater representative which retains the young through embryological development to the 2nd instar. *Darwinula stevensoni* and other species of *Darwinula* are known to care for their young through embryological development to the first instar only (McGregor 1968).

Two hundred and fifty females were dissected and examined for the broods. All except six were ovigerous and carried either eggs or juveniles or both. No females carried juveniles older than 2nd larval stage. The total number of eggs plus juveniles brooded per female varied from 1-20 but 14-18 was very common.

Broods from 25 females were isolated separately in 'cavity blocks'. They yielded 173 eggs, 78 first instar larvae, and 16 second instar larvae. These were allowed to develop in water and sediments from the culture tray. One hundred from 173 eggs hatched out into first instars. Of these, 50 moulted to 2nd larval instars. Only 20 moulted to 3rd instar, and 15 to 4th instar larvae. No development took place in the laboratory beyond the 4th larval stage. These observations are adequate enough to infer that eggs and early instars are capable of development even outside the incubatory chamber. As the first larvae are stationary in habit broodcare could be an adaptation to ensure protection and better chance of survival of juveniles.

In another experiment, 50 ovigerous females were isolated to observe the period of larval release. Water and organic detritus were provided from the culture tray. It was observed that larvae were released for about six weeks. Almost all the instars released (600) were the second larval stage. During this period only ten eggs and five first stage instars were seen in the subculture.

These could have been released accidentally or from two specimens which died during experimentation.

#### PROCESS OF MOULTING

Relatively little is known about the process of moulting. Wolgemuth (1914) from his studies on *Cyprinotus incongruens* Ramdohr 1808 believed that the organism sheds its antennules first, then the other appendages in order towards the rear. Schreiber (1922) observed the moulting of *Eucypris virens* (Jurine) 1820 and concluded that rear appendages were the first to be freed from the old skeleton and antennules were the last. The process may vary with different species.

In the present studies complete moulting of two 2nd instar juveniles was observed. The moulting took about two hours. It was accompanied by barely perceptible movements with prolonged intervals in which the animal is apparently motionless and lying flat on its side. The branchial plates were in normal motion. The valves were slowly spread open to an abnormal width. The maximum opening of the valves at the anterior end was 96  $\mu$  and 50  $\mu$  at the posterior. The first breaking of the exoskeleton took place with the opening of the left valve. This was followed by the replacement of the right valve. After about one hour, the body wall was separated from the lining of the valves in the dorsal part of the head region. Antennules were then withdrawn slowly from their sheaths. The antennae followed this sequence and then the other appendages. The shell in the posterior region was freed using the antenna, and the organism crawled out of the old skeleton. It lay motionless for some time, presumably for the hardening of the raw skeleton, and moved again with the help of the antenna.

#### ONTOGENY

Claus (1868) working on *Cypris ovum* Jurine and *C. fasciata* Müller made the first extensive study on the ontogeny of ostracods. Later the morphology of various instars of other species have been described by Müller (1894), Schreiber (1922), Scheerer-Ostermeyer (1940) and Kesling (1951). At first sight, their reports seem to show a great variation; but, a detailed comparison reveals that the disparity arises not from the observations of number of appendages in each instar, but from the interpretation of appendages in juveniles. The appendage which Müller referred to as an incipient furca has been described by Claus as second leg. Thus the apparent order of appearance of the various appendages differs considerably according to different authors, although their observations are in agreement.

Schreiber (1922) and Scheerer-Ostermeyer

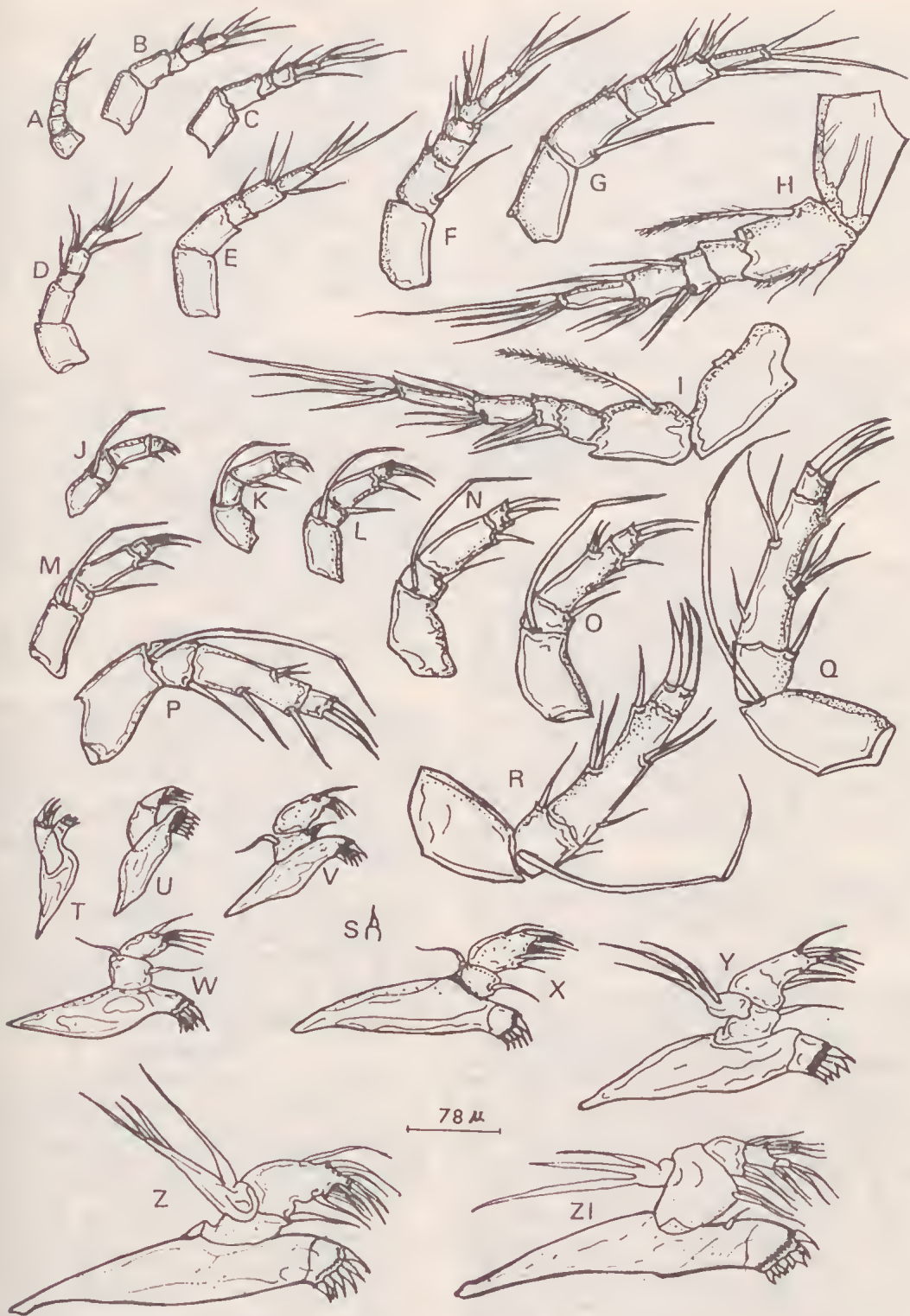


FIG. 1—A-I Antennules of instars 1-9. J-R Antennae of instars 1-9. S-Z<sub>1</sub> Mandibles of instars 1-9.



(1940) followed Müller (op. cit.) in their studies on ostracod ontogeny. It is seen that the number of appendages for each instar is the same in both systems followed by Claus and Müller. In Müller's system the furca appears early and the body appendages are added in orderly sequence from the anterior to posterior. This system seems to be a widely accepted one (Kesling 1951). In *Gomphocythere australica* the sequence of the addition of appendages at each moult followed that described by Müller. The furca, however, became rudimentary at 5th larval stage and in the adult is represented as two thin juxtaposed lamellae.

#### EGG

Eggs are grey-white, nearly spherical, opaque, and approximately  $90\mu$  in diameter. As development progresses they turn translucent. There is a soft single-walled, white opaque shell. The opaque nature of the shell makes it impossible to observe the egg contents. When the larvae hatch, a split occurs dividing the shell into two equal halves, which usually remain attached.

#### FIRST INSTAR

Carapace elliptical,  $162\mu$  in length and  $112\mu$  in width; soft and weakly sclerotized and transparent. Eye is large. The instar has three pairs of appendages; antennule, antennae and mandible (Fig. 1A, J, S). Antennule with four podomere and only three setae, two of which are on the terminal podomere. The second podomere with spine at its joint with the terminal podomere. The antenna with four podomeres with two setae on the terminal podomere and one on the subterminal podomere. The basal podomere with a two-jointed spine. Mandible short, stump-like, comprises two short podomere set on an elongate extension of the body, with a strong seta at the terminal end.

The instar is stationary and antennules and antennae are utilized for catching food. Duration 14-18 days. Generally, moulting takes place on the 16th day.

#### SECOND INSTAR

Larvae are released as 2nd instars only. It is very difficult to observe the detailed process of the laying of larvae because of the opacity of the shell. However, observations suggest that the ovigerous female stands motionless in the organic detritus with the valves partially opened at the beginning of the process. They are released singly. It appears that the 2nd and 3rd legs assist in releasing the larvae.

Description as follows: length  $192\mu$ , height  $124\mu$  and width  $109\mu$ . When newly moulted it is transparent. Shell slightly enlarged but the rim still very simple. Muscle scars clearly seen. Eye is approximately the same size as in the first instar and still located near the middle of the shell. Antennule (Fig. 1B) composed of four distinct podomeres. Antenna (Fig. 1K) consists of four podomeres, the terminal podomere has two setae, each of the podomeres with one seta each. Mandible (Fig. 1T) greatly altered

from its structure of the first instar. The terminal podomere is completely set off and equipped with teeth at its distal end; in addition it has a palp of two distinct podomeres.

'Anlagen' of two new appendages are added; these are interpreted as the primordia of maxilla and furca. The maxilla is swollen with a pointed projection at its anterior ventral side. In the dorsal posterior area a slight lobe is seen which may be interpreted as the 'anlagen' of the exopodite plate. The furca is represented by a strong stump-like projection of the body with a long terminal seta. The mouth has shifted to the middle of the body. The duration of this stage is 12-17 days but 14 days is quite frequent.

#### THIRD INSTAR

During this stage no new 'anlagen' are added, a further development of the already present appendages takes place, length  $224\mu$ , width  $135\mu$  and  $120\mu$  in height. Antennule (Fig. 1C) consists of the same number of podomeres as in the previous instar. Antenna (Fig. 1L) has the same form and essentially unchanged. Mandible stronger and slightly elongated (Fig. 1U). Terminal end of the maxilla (Fig. 2A) divided into 'masticatory' processes but without a palp. Exopodite bears six setae. Furca, basically the same, a stump of the body with a long seta. Mouth still in a median position.

The duration of this instar is from 20-26 days. Generally moulting takes place on the 24th day.

#### FOURTH INSTAR

Length  $259\mu$ , width  $160\mu$  and height  $120\mu$ . Antenna has five podomeres (Fig. 1M), with marked increase in length. It still maintains the same approximate form. The second podomere of the protopodite of mandible (Fig. 1V) separated from the basal podomere, but the general form remains the same. The maxilla (Fig. 2B) approaches a definite form with an increase in the number of setae on the respiratory plate. There is a definite 'anlagen' of the first thoracic leg, a roughly triangular plate with a ventral lobe hanging free with a short claw (Fig. 2H). Furca basically remains the same in shape and size.

The fourth instars survived for 20 days but did not moult. The description of the subsequent instars is based on field-collected material.

#### FIFTH INSTAR

Length from  $312$  to  $320\mu$ . Shell thicker and with more complex rim. The colouration very similar to that of adult (brownish). The antennule (Fig. 1E) consists of the same number of podomeres. The antenna (Fig. 1N) increased in length, the mandible (Fig. 1W) well built. The palp of the maxilla (Fig. 1C) divided into four podomeres, the respiratory plate larger and equipped with thirteen setae. The first thoracic leg (2I) three-segmented with a claw at the distal end. The basal segment is equipped with a pair of setae.

'Anlagen' of second thoracic leg (2N) developed as an elongated, backwardly-directed process of body terminating in very blunt clawlike process. Attach-





FIG. 2.—A-G Maxillae of instars 3-9. H-M 1st thoracic leg of instars 4-9. N-R 2nd thoracic leg of instars 5-9. S-V 3rd thoracic leg of instars 6-9.

ment immediately behind the first thoracic leg. The furca is reduced and is represented by a short projection of the body, a short spinc.

#### SIXTH INSTAR

All appendages are present for the first time in the sixth instar. The remaining ontogenetic stages show further development of the appendages and the 'anlagen' and the completion of the sex organs.

Sixth instar length  $368\mu$  antennule (Fig. 1F) with six podomeres, with well-developed spines and setae. Antenna (Fig. 10) with four podomeres. Claws well-developed and chitinated. Mandible (Fig. 1X) slightly longer. Maxilla (2D) also reached its definitive form; in this instar the number of setae are also increased. First thoracic leg (2J) fundamentally remained the same, except for a slight increase in size. Second thoracic leg (Fig. 20) four-segmented with the terminal segment pointed to form a claw.

The anlage of the third thoracic leg (2S) is an elongate, backwardly directed process of the body with a stubby chitin at the end. It resembles the anlage of the second thoracic leg in the fifth instar.

#### SEVENTH INSTAR

Length  $448\mu$  to  $480\mu$ , all appendages well-defined and the anlagen of the sex organ. The antennule (Fig. 1G) consists of six podomeres. The antenna (Fig. 1P) approached the definitive form with well-developed claws. Mandible (Fig. 1Y) increased in size with an exopodite with three setae. Maxilla (Fig. 2E) greatly enlarged. Exopodite plate (branchial plate) much larger and equipped with a greater number of setae. First two (Fig. 2K, R) pairs of thoracic legs five-segmented, well built and of definitive form. Terminal segment pointed to form a claw.

The structure of the furcal rami remains the same, as in the previous segment. There is no development of genital lobes and the external genitalia.

#### EIGHTH INSTAR

The eighth instar resembles the adult very closely except for size and sex dimorphism. It possesses all the appendages in the definitive form. The genital lobe makes its appearance as a rudiment. The appendages have no marked change from the previous instar. This instar measures  $520\mu$  to  $592\mu$  in length.

#### NINTH INSTAR (adult form)

The adult differs from the eighth instar in the external chitinous genital structure and the completion of sex organs in both sexes. The appendages are strongly chitinated, eye is median, valves of the shell are dark.

There is a distinct sex-dimorphism both in size and shape of the individuals. The lengths of male and female are  $700\mu$  and  $860\mu$  respectively. Caudal rami are very different, forming juxtaposed thin lamellae curving anteriorly, with a plumose seta at their base. Posterior end of each lamella is divided into three successive short 'liquiform lobules' clothed at the tip with long diverging cilia.

The copulatory appendage of the male is very massive, terminating in a quadrangular plate.

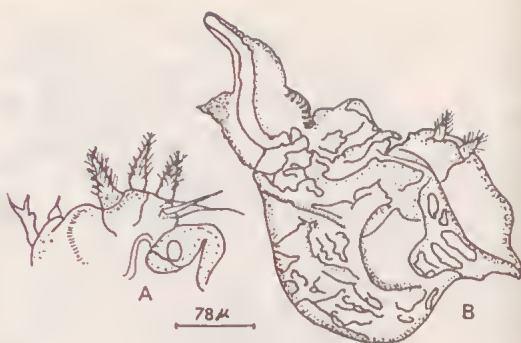


FIG. 3—A. Furca of female. B. Penis.

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# SOME ASPECTS OF THE ECOLOGY AND NEST MICROCLIMATOLOGY OF THE MEAT ANT, *IRIDOMYRMEX PURPUREUS* (SM.)

By G. ETTERSHANK\*

**ABSTRACT:** The nest of the meat-ant (*Iridomyrmex purpureus*) was studied in an arid region of Australia. Temperature (above and below soil level), heat flux, moisture and respiratory gases were measured, and soil characteristics determined. These enabled the conditions in which ants live in the nest to be described. The possibility of treating the nest as a natural calorimeter was examined and rejected, but a method of determining nest metabolism by collection of gas samples under a hood on the nest was utilized; this method also led to a back-calculated estimate of population. The varying nature of the nest 'decoration' was considered and some conclusions drawn on its functions.

## INTRODUCTION

The meat ant, *Iridomyrmex purpureus* (Sm.) lives in nests in the ground. Details of the biology and nest structure are given elsewhere (Ettershank, 1968; Greaves, 1939; Duncan-Weatherley, 1953; Anon., 1956). The nests vary from small, rather inconspicuous mounds with a single opening to extensive nests up to 10.7 m across, and 0.6 m high with 1061 entrance holes (Anon., 1956). In many areas these nests are covered with small pebbles or ironstone nodules about 2-4 mm diameter, or twig fragments, gumnuts or grass stem fragments. Most of the galleries are concentrated in the upper 15 to 25 cm of the mound, but some of the galleries and shafts may extend two to three m into the ground. The nests are situated on well drained sites, usually associated with trees, but never in situations where the tree canopy is closed. The workers forage on trees, collecting honey-dew from homopterous insects and nectar from floral and extrafloral nectaries; they also scavenge dead and dying insects. The species occurs over much of Australia, from heavy rainfall areas through to semi-desert with an average annual rainfall of 20 cm.

The present paper describes an investigation into conditions within the nest of the meat ant—involving measurement of temperature, radiation, heat and water movement, humidity and respiratory gases—in an arid mallee-scrub area 112 km

south of Broken Hill, N.S.W. The aim of the project was to obtain information on the nest microclimate, and to ascertain whether temperature measurements could be used to estimate the overall metabolism of the nest (that is whether the nest could be treated as a natural calorimeter, Engelmann, 1966), and whether metabolism could be estimated by a gas analysis method.

Previous studies of temperature in ant nests have been conducted purely for their own sake, and all relate to species in Europe and North America. No previous study in Australia has been concerned with nest microclimate, water status or energetics. Duncan-Weatherley (1953) made surface observations on nest form, but was more concerned with behavioural aspects, particularly those relating to foraging. Greaves (1939) and Anon. (1956) were primarily concerned with the control of the meat ant as a pest species, a status it acquires in only relatively few places. Ettershank (1968) examined the three dimensional relations of the gallery system, and found that each entrance on the nest opened into a separate set of galleries; nest entrances were found to occur in a somewhat regular pattern. The only other extensive study of an Australian ant species is that of Saunders (1967, 1969) on the effects of *Aphaenogaster* spp. on pasture grasses in North Queensland. There is also a somewhat inconclusive study by Nel (1965) on the effects of temperature

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and humidity on water loss in workers of the meat ant.

Ecologically equivalent types of nests to that of the meat ant are those of the American harvester ants of genera *Messor*, *Veromessor* and *Pogonomyrmex*. Golley and Gentry (1964) attempted to estimate energy flow in *Pogonomyrmex badius* nests in South Carolina; in the course of this study soil temperatures at various depths from 150 cm to the surface were taken for three days in January and July, but these are not reported in their paper in detail, nor is their technique given. They considered the summer and winter soil temperatures at 90-100 cm depth to be a 'rough estimate' of the temperature at which the ants were living underground. A graph showing daytime surface temperatures in July, May, October and February, and activity on the mound indicates that the ants became active in the morning when the surface temperature reached about 32°C, but later in the day the ants were active between 15 and 50°C. Data for temperatures at surface, 30, 60 and 90 cm were taken only at four-hourly intervals for a 'typical' summer and winter day; there is, moreover, a disparity between their 'typical' surface temperatures and those shown in their graph. They also undertook an analysis of productivity of this ant. A mark-recapture technique was attempted to estimate populations, but total excavation of colonies showed that only a portion (about 10%) of the population foraged and was thus available for marking. Nest populations were estimated at between 4,000 and 6,000, and there were 0.0027 nests per sq m. They calculated that 14.2 Kcal to 47.7 Kcal m<sup>-2</sup> yr<sup>-1</sup> was used in respiration, and 0.09 Kcal m<sup>-2</sup> yr<sup>-1</sup> of new biomass was produced each year. This ant is considered to be graminivorous; the field produced 22 Kcal m<sup>-2</sup> yr<sup>-1</sup> of seeds, so their estimates of gross productivity broadly spanned the primary productivity: they thought the difference could be made up in insectivory. Other consumers were the sparrow (4 Kcal m<sup>-2</sup> for a 150 day season) and the mouse (7.17 Kcal m<sup>-2</sup> yr<sup>-1</sup>). Golley and Gentry point out that the primary sources on which these estimates are made are not equally reliable. Density per nest and soil temperatures were based on only a few observations, and the 'estimates of production are least reliable'. To this list should be added oxygen consumption, as this was based on the uptake of a relatively few workers in a simple, non-replacement respirometer. A graph of their data for oxygen consumption versus temperature shows the usual exponential rise, but the data were not transformed to logarithms and a regression line fitted, which is the usual procedure in such cases. This

study should be regarded as no more than a first approximation—and yet it is the only one of its kind for ants to date, and indeed such analyses are relatively uncommon for any communities or smaller groups of taxa (Engelmann, 1966).

The behaviour of soil, and particularly of the moisture it contains, when exposed to solar radiation has been intensively studied by the methods of agricultural physics. Geiger (1965) discusses in detail the present state of knowledge of heat flow in soils, temperature stratification in the ground, and temperature fluctuation on a diurnal and annual scale. Geiger (1965) and Rose (1966) discuss a mathematical model for heat flow in an idealized soil, based on the assumption that temperature change at the soil surface is a sinusoidal function. Under these conditions, the temperature at any depth may be readily predicted. While this condition is met fairly well on an annual basis, it is not met in diurnal temperature change; not only is the assumption of a sinusoidal cycle violated, but changes in thermal conductivity with depth are not allowed for in the model. For an ideal soil, the daily temperature fluctuation at 35 cm falls to 5% of its surface value, taking a typical value of the thermal conductivity. For the annual wave, the corresponding depth for 5% for the surface fluctuation is 6.7 m. Geiger (1965) gives several examples of soil temperature profiles for annual and diurnal cycles, and discusses the modifying effects of vegetation.

Slatyer and McIlroy (1961) consider energy flow in soils further; it can be shown that the total solar energy arriving at the ground surface,  $R_s$ , may be partitioned as follows:

$$R_s(1-a) = R_L + G + H + LE \text{ where}$$

$R_s$  = flux density of total short-wave radiation

$a$  = albedo

$R_L$  = net flux density of long-wave radiation emitted from the surface

$G$  = heat flux density into the ground

$H$  = actual heat flux density into the atmosphere

$L$  = latent heat of vaporization of water

$E$  = evaporation rate, including transpiration.

Some of these may be measured fairly easily. A net radiometer records incident radiation on its upper surface ( $R_s$ ), and on its lower surface it subtracts reflected shortwave radiation ( $R_s \times a$ ) and emitted longwave radiation  $R_L$ ; the radiometer output is thus an electrical analogue of net radiative input. The heat-flux density moving down into the ground (conventionally considered positive), or back towards the surface (negative) may be measured by heat flux plates. The latent heat of vaporization of water being known, this leaves



two unknowns (H and E), the sum of which may be readily obtained from the other components. The component of major interest here is E, the evaporation rate, so the problem comes down to partitioning the remaining energy into the amount used in warming the air above the soil (H) and that used to supply the latent heat, usually called respectively the sensible and latent fluxes. This problem was considered by Bowen in 1926, and the so-called Bowen ratio provides a method of partitioning by the Energy Balance Method; Slatyer and McIlroy (loc. cit.) describe the necessary instrumentation and working methods, and provide the necessary tables and a sample work sheet for computation. The data required are wet and dry bulb temperatures at two levels above the surface being studied, as well as the radiation flux described above.

## MATERIALS AND METHODS

Suppliers of equipment referred to by superscript numbers in this section are: 1. Yellow Springs Instrument Co., Yellow Springs, Ohio, U.S.A. 2. Swissteco Pty. Ltd., Hawthorn, Vic., Australia. 3. Middleton and Co. Pty. Ltd., South Melbourne, Vic., Australia. 4. Curtis Instrument Co. (Model 150-SP), Mount Ciseo, N.Y., U.S.A. 5. The Tintometer Ltd., Salisbury, England, U.K.

### 1. LOCALITY

Nests of the meat ant are found in open spaces in the sparse mallee scrub which covers a series of old, low sandhills running generally E.-W.; the area is known locally as the South Ita Sandhills, and is in the northern part of Coombah Station, 112 km due south of Broken Hill. Brough & Ettershank (unpublished data) found by line transect analysis that the mallee (*Eucalyptus dumosa*) canopy overlaid 15% of the ground, and other tree species less than 1%; porcupine grass (*Triodia* sp.) covered 23% of the ground, and all other grasses and herbs less than 1%. Nests are, consequently, situated adjacent to the trees on which the workers forage, but they are shaded, at most, only in the early morning and late evening. The ants clear all seedlings and wind-carried plant parts from on and around the nest—the ground around well established nests may be clear for a distance of one to three metres from the nest margin. In addition, due to the clumped life-form of *Triodia*, there are often large, naturally bare areas around nests.

### 2. TEMPERATURE MEASUREMENT

Temperatures were measured with a six-channel, multirange YSI Telethermometer<sup>1</sup> fitted with an additional switching box to accommodate ten further probes. The instrument can be read reliably to 0.05°C from 0°C to 50°C. The thermistor probes used were YSI type 401, which have

a heavily insulated lead, and the thermistor bead enclosed in a radiation-reflecting cap.

The probes for soil measurements were carried across to the required position by taping them to a steel wire stretched across the nest, at least 10 cm above the surface. They were always inserted on the northern (equatorial) side of the wire, using an instrument consisting of a grooved steel rod, 90 cm long, fitting snugly inside a slotted aluminium tube.

A small detachable collar caused the tube to protrude 20 mm past the end of the steel rod, and this retained a small, pointed, disposable plastic cap which protected the thermistor probe during insertion. In use, the lead was first lubricated with talcum powder, laid in the groove and the tube rotated to cover it. The entire assembly was inserted into the nest or soil to the required depth; the small collar at the base of the steel rod was removed and the aluminium tube retracted from the plastic tip. The inner rod was then rotated 180° so that the lead could be peeled from the groove and held firmly to the ground while the inserter was removed. The small hole remaining was filled with soil tamped in with a thin dowel.

To ascertain if there was appreciable heat pick-up in the exposed part of the lead, two probes were placed side by side in the soil. The lead of one was brought vertically to the soil surface and back to the measuring instrument taped to a wire as described above; the second was brought horizontally back to the measuring instrument in a trench 5 cm deep, and then soil was packed firmly around both leads. Readings taken every fifteen minutes from 10 a.m. until 2 p.m. on a clear summer day gave the same temperature for each probe throughout.

Air temperature leads were fitted with tubular, chromed-brass radiation shields. Wet bulb temperatures were obtained with a fast response 'banjo' thermistor probe covered with lens tissue and wetted at the start of each reading series with distilled water applied with a dropper. It was contained in a radiation shield and aspirated with a fan driven by a battery-powered motor. Its performance was compared with that of a standard Assman ventilated psychrometer, and it gave results accurate to within the accuracy of the instrument.

### 3. RADIATION AND HEAT FLOW

Net radiation at one metre above the nest was recorded with a Funk Net Radiometer<sup>2</sup> (Platt and Griffiths, 1964), fitted with polythene shields and ventilated with dry air. Heat flux in the soil was measured with flux plates<sup>3</sup> (Philip, 1961), connected in parallel to obtain average values for the nest. The plates were buried to a depth of 5 cm in the

nest surface between entrances, and the soil repacked tightly on top of them. The leads were run underground to the nest margin by the shortest route. The ants repaired the damage to the nest surface, and the position of the soil plates was not easily determined by inspection.

As both the radiometer and the flux plates are thermopile devices, with low internal resistance, they should not be connected to low impedance measuring devices because of the Peltier cooling and other errors generated in such a circuit. Each was connected to a separate, integrated-circuit amplifier, with an input impedance of 10K ohms and an amplification of  $\times 100$  for the radiometer and  $\times 1000$  for the flux plates. The electronic components were housed in a sealed box and buried 0.6 m in the ground to obtain reasonable temperature stability (daily variation  $1.0^{\circ}\text{C}$ ). Read-out was by a taut-band, multi-ranged meter (1, 2.5 and 10 volt ranges), with provision for connecting a chart recorder, and for integrating over time using mercury coulometers.<sup>4</sup>

#### 4. RELATIVE HUMIDITY.

Two long (25 cm) hollow needles were inserted into galleries in the nest, and air samples were aspirated from these using a 100 cm<sup>3</sup> syringe, containing a piece of BDH cobalt thiocyanate paper (Solomon, 1957). The air sample was allowed to equilibrate for 30 minutes, and the relative humidity determined by comparison between the paraffin-mounted test paper and standards on a colour wheel in a Lovibond Opaque Comparator<sup>5</sup>. Samples for comparison were also drawn from a needle in a 'synthetic gallery', constructed at a depth of 20 cm by drilling a 2.5 cm hole, inserting a needle carrying a 2.5 cm plastic disc so as to leave a cavity about 4 cm deep, and packing soil on top. Finally, six perforated plastic vials containing cobalt thiocyanate papers were buried at a depth of 20 cm for several days before they were retrieved. All humidity determinations were corrected for temperature using tables (attributed to M. E. Solomon) supplied by the manufacturer.

#### 5 RESPIRATORY GASES

Air samples were aspirated from the nest and soil through the needles described above. Samples were also taken from a hood with metal sides and clear plastic top, measuring 25.6 cm on each side and 5.1 cm high, fitted with a fan on a shaft protruding through the top (with which the air in the hood could be stirred) and a rubber port to withdraw air samples with a 10 cm<sup>3</sup> syringe. The volume of the hood, determined by filling it with water, was 3,350 cm<sup>3</sup>. The hood was pressed down firmly onto the surface of the soil or the nest, and

moved about slightly to obtain a close fit. Samples were drawn after 25 minutes; gas in the hood came into equilibrium after 30 minutes, as the rate of uptake dropped off after this time. Analyses were carried out in the field with a Scholander Gas Analyzer (Scholander, 1947), fitted in an insulated jacket and with the water bath controlled by a thermostatically-controlled 12-volt heater and stirrer. Sodium sulphate crystallized out of the acid rinsing solution at low temperatures, and it was necessary to keep the bulk supply in a warmed, insulated box.

Collection of gas samples under a hood is a practice established in agriculture, where it is used to obtain estimates of carbon dioxide production on plots (Koept, 1952; Ellis, 1966). In this technique, the hood sits on a collar which is permanently positioned at the collection site; carbon dioxide is drawn into an analysis vessel, dissolved in alkali and electrolytically titrated. The use of a permanent collar was tried in nests at Bacchus Marsh, but caused such perturbation that it was abandoned: even after several days, the ants were still trying to excavate the collar if it was not buried deeply, or bury it if it was. The consolidated surface of the nest provides a good contact for the hood provided some care is taken to scrape off any high spots by moving the hood back and forth.

Oxygen consumption rates for single ants were obtained using an electrolytic replacement respirometer (Ettershank, unpublished).

#### 6. SOIL CHARACTERISTICS

Soil moisture was determined gravimetrically (Slatyer & McIlroy, 1961); samples were collected into aluminium containers, care being taken to exclude ants from the samples. Three nests were sampled on an 8  $\times$  8 grid, 30.5 cm between sample points. Additional samples were collected during other phases of the study as required.

The specific gravity of the soil was obtained by a method based on that of the Standards Association of Australia (1966). A known weight ( $W_1$ ) between 80 and 100 grams of oven dried soil was placed in a 500 ml volumetric flask and the flask nearly filled with de-ionised water. Air was removed under vacuum and the flask filled to the calibration mark with de-aired water. The flask plus soil and water was weighed ( $W_2$ ), emptied, cleaned, filled to the calibration mark with de-aired, de-ionised water and reweighed ( $W_3$ ). The specific gravity is given by the expression  $W_1/(W_1 - W_2 + W_3)$ .

A more realistic measure for soils is the bulk density, i.e. weight per unit volume of soil, including natural voids. As the nest soil contains



tunnels made by the ants, the usual sand replacement method could not be used, and a volumetric method (Slatyer & McIlroy, 1961) was applied. Blocks of soil were excavated and brought to the laboratory. Loose soil was removed from the ant galleries (when applicable), and the sample was dried and weighed. It was then sprayed with lacquer to retain its shape, redried and dipped in molten paraffin wax at 105°C, then allowed to drain in the same oven for ten minutes, during which time the wax was drawn into the surface of the soil block. On cooling, a consolidated, waterproofed block resulted. The volume of each block was determined by immersion in a beaker of water containing a little 'Tween 80' detergent. Adhering bubbles were removed by a jet of water from a pipette, and a hook gauge arranged so that its tip just dimpled the surface. The block was removed and drained carefully back into the beaker. Water was added from a burette to restore the level, giving the volume of the block.

The specific heat of the soil was obtained by simple calorimetry. The calorimeter consisted of a light aluminium can of 220 ml capacity, fitted with a polyurethane foam jacket and a clear plastic lid through which a precision mercury-in-glass thermometer was inserted. About 50-70 grams of oven-dried soil was accurately weighed and placed in an oven at 105°C. The calorimeter was cleaned, dried and weighed, placed in its jacket and 100 ml of distilled water added. The calorimeter and water were allowed to equilibrate, and the temperature taken. As quickly as possible, the soil was removed from the oven and tipped into the calorimeter, the lid placed on and the mixture stirred with the thermometer. The temperature rose until soil, water and can were in equilibrium, when the temperature was read. Then

$$C_s = \frac{(W_{al} C_{al} + W_w) (T_{eq} - T_w)}{W_s (T_s - T_{eq})} \text{ cal gm}^{-1} \text{ deg C}^{-1}$$

where

- $W_{al}$  = weight of calorimeter can
- $C_{al}$  = specific heat of aluminium
- $W_w$  = weight of water (specific heat = 1)
- $W_s$  = weight of soil
- $C_s$  = specific heat of soil
- $T_w$  = initial temperature of the water
- $T_s$  = initial temperature of the soil
- $T_{eq}$  = equilibrium temperature of the mixture.

The thermal capacity, defined as the heat required to raise the temperature of 1 cubic centimetre of soil one degree Celsius (Geiger, 1965) is the product of the specific heat and bulk density, and has units  $\text{cal cm}^{-3} \text{ deg C}^{-1}$ .

Mechanical analysis of the nest and nearby soil, as well as soil structure studies using soil blocks impregnated with fluorescent wax, are discussed by Ettershank (1968).

## RESULTS

A preliminary survey of the range of values to be expected, using mercury-in-glass thermometers, was made in February 1967. (Fig. 1). This indicated that mid-summer temperatures could not be studied with the more accurate electric thermometers. A detailed study was carried out in September 1967, using four temperature probes in the nest and four in the surrounding soil at depths of 2.5, 7.6, 23 and 38 cm and four air temperatures were taken at heights of 5, 10, 20 and 40 cm above ground. Net radiation was recorded, but no flux plates were available for soil heat measurements. Data were collected every half hour for four days, during which time there was virtually no cloud and only gentle breezes. Fig. 2-5 show the nest and soil temperatures for the four days, and Fig. 6-9 the corresponding air temperatures. Fig. 10 and 11 show isotherms for nest and adjoining soil on one day (29.ix.67). Fig. 12 displays the net radiation recorded with average nest and soil temperatures.

Full instrumentation was not available until August 1968, when data on temperature were obtained at two surface stations, 10, 20 and 40 cm depth, both in the nest and in the adjoining soil 1 m from the nest margin. Air temperatures were taken at 10, 20, 40 and 80 cm above ground, and wet bulb temperatures were read at the 10 and 80 cm levels. Net radiation was recorded one metre above the nest, and two flux plates were

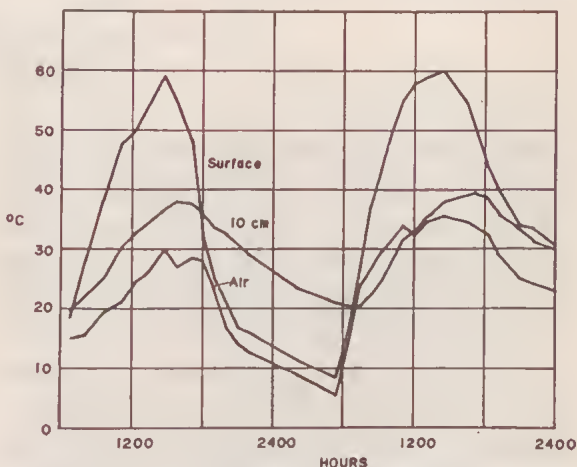


FIG. 1—South Ita Sandhills—air, surface and 10 cm temperatures of a meat ant nest in summer (February, 1967).



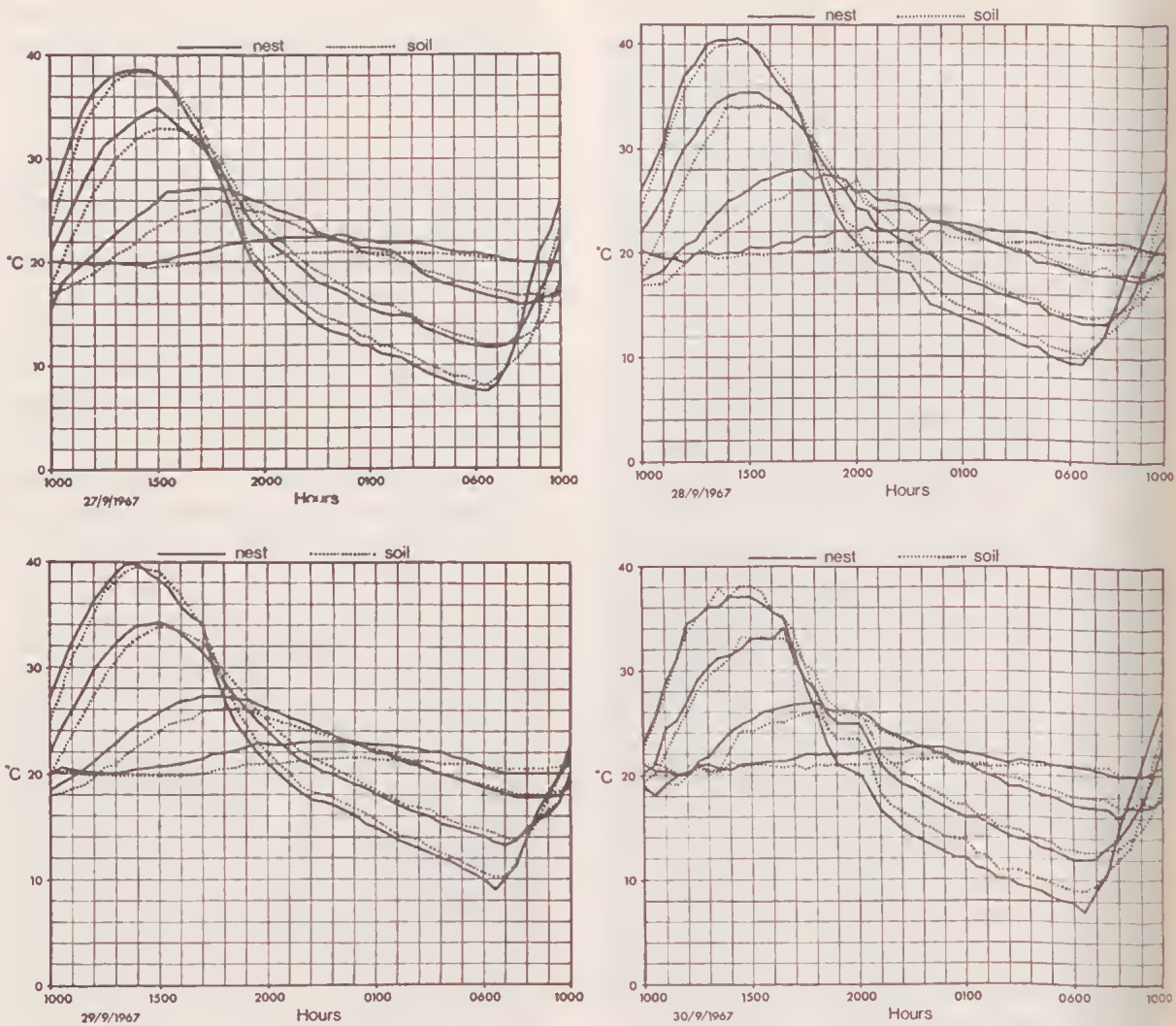


FIG. 2-5—South Ita Sandhills—2.5, 7.6, 23 and 38 cm temperatures in a meat ant nest and in the adjoining soil: 27-30.ix.67.

installed two days before recording started. Due to weather conditions, only one record exceeding 24 hours was obtained (13-14.viii.68) and these data are presented in full: Fig. 13 shows the nest and soil temperatures, Table 1 selected air, nest and soil temperatures for a particular part of the period (see Discussion) and Fig. 14 the net radiation and soil heat flux.

At the same time, gas and humidity samples were obtained; Fig. 15 presents data for oxygen consumption and carbon dioxide production, calculated on the basis of samples drawn from the respiration hood, and expressed as cubic millimetres of gas per square centimetre per hour, plotted against surface temperature on the nest.

Regression lines of gas volumes on temperature were fitted (Sokal & Rohlf 1969); the slopes of the lines are very highly significant ( $p < 0.001$ ).

Samples of air drawn from the galleries showed the internal state of the nest. The gas composition (stated as mean  $\pm$  standard error) was oxygen  $20.729 \pm 0.0195\%$  and carbon dioxide  $0.183 \pm 0.0165\%$ . On the other hand, air samples drawn from the respiration hood placed on the ground and from the 'synthetic gallery' were indistinguishable from the normal free air values of oxygen  $20.946 \pm 0.002\%$  and carbon dioxide  $0.033 \pm 0.001\%$  (CRC Handbook of Chemistry and Physics, 48th ed.).

Relative humidity in the nest and surrounding

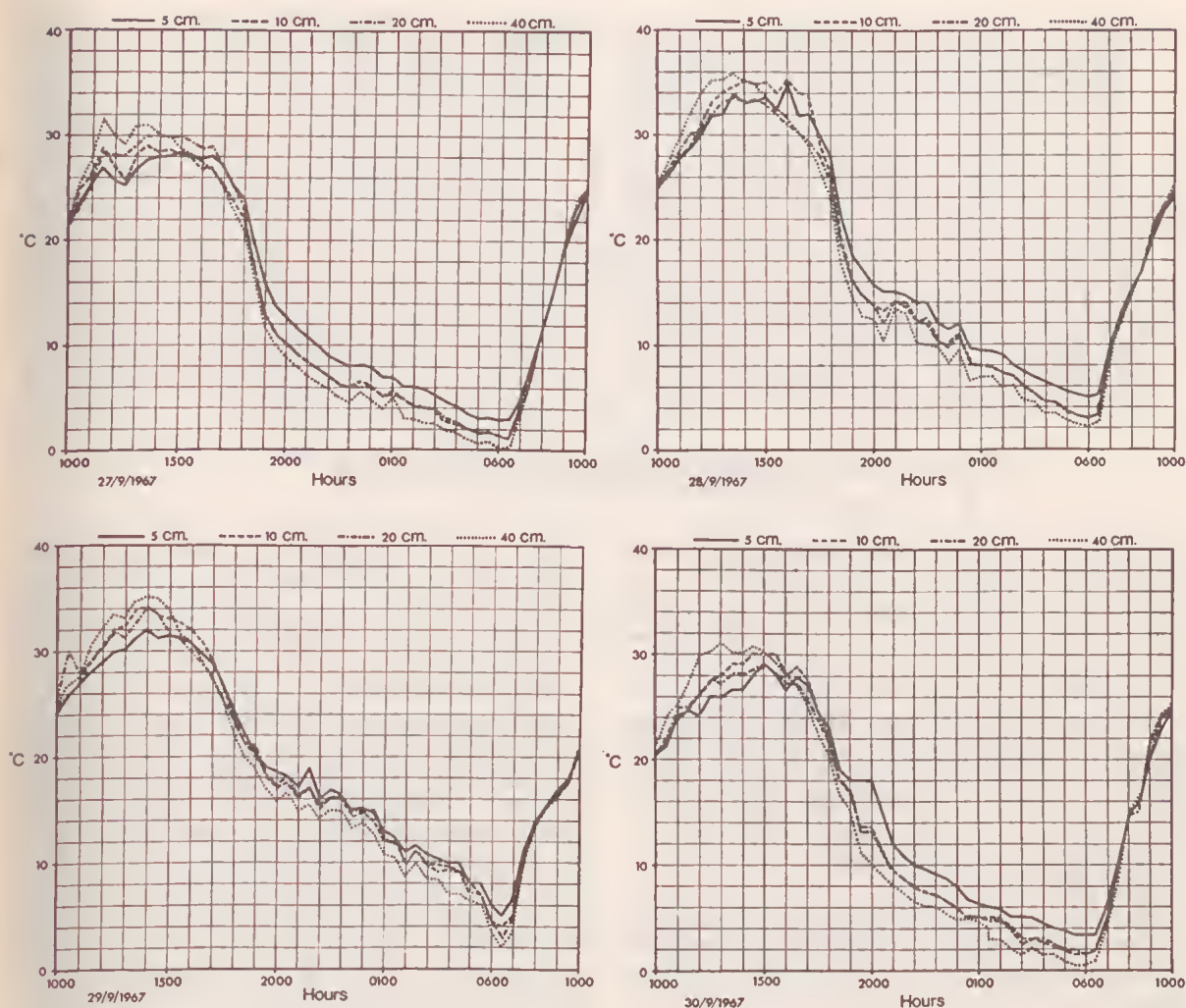


FIG. 6-9—South Ita Sandhills—air temperatures at 5, 10, 20 and 40 cm above ground: 27-30.ix.67.

soil did not seem to be correlated with site, temperature or time of day, and was surprisingly constant (mean  $\pm$  standard error,  $68.3 \pm 1.63\%$ ).

Table 2 shows the soil moisture obtained by sampling on  $8 \times 8$  grids enclosing three nests and part of the soil all around, in the same general vicinity of the nest used for temperature studies. In each case, the samples were classified as nest or soil, and an average moisture calculated for nest and soil samples. These were tested using Student's *t*, and it will be seen that in each case the nest soil contained more water.

The specific heat of nest soil was  $0.20 \text{ cal gm}^{-1} \text{ deg C}^{-1}$ , and the bulk density  $1.71 \text{ gm cm}^{-3}$ , yielding a thermal capacity of  $0.34 \text{ cal cm}^{-3} \text{ deg C}^{-1}$ , while the specific gravity was 2.62; each is the mean of three determinations. The thermal

capacity of the soil two metres from the nest was also  $0.34 \text{ cal cm}^{-3} \text{ deg C}^{-1}$ , and the specific gravity 2.66, a trivial difference; these are also based on three determinations from two samples each. Corresponding figures for a nest of the same species from Baechus Marsh (Victoria), some 800 km south, are: thermal capacity of the nest soil  $0.34 \text{ cal cm}^{-3} \text{ deg C}^{-1}$ , but of the gravel covering the nest 0.27; specific heat respectively 0.20 and  $0.17 \text{ cal gm}^{-1} \text{ deg C}^{-1}$ ; and bulk density, 1.72 and  $1.57 \text{ gm cm}^{-3}$ .

Table 3 shows the calculated evaporation rates from the nest for the period 8 a.m. on 13.viii.68 to 10 a.m. on 14.viii.68. Rates are given in units of millimetres of water per day: that is the amount of water that would be lost from a freely evaporating water surface receiving the same energy



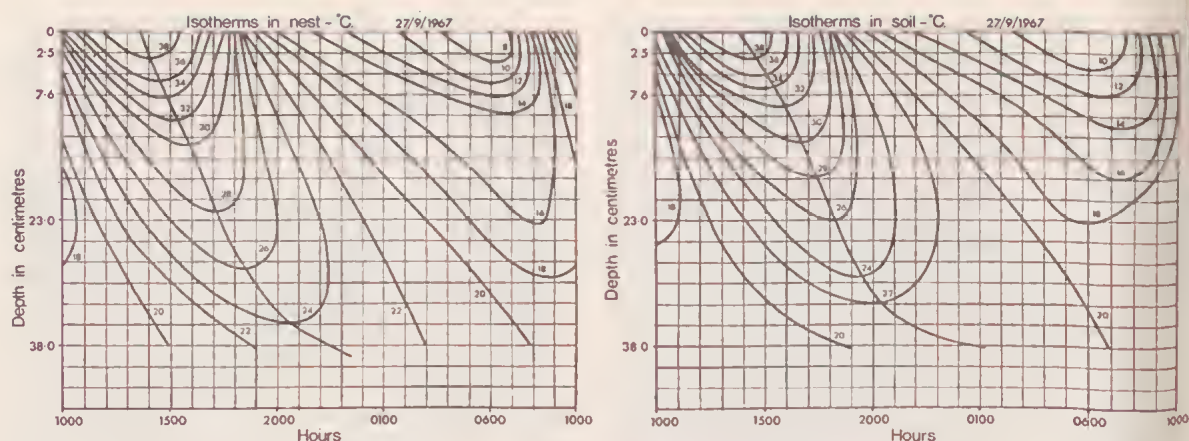


FIG. 10-11—South Ita Sandhills—isotherms in the nest and adjoining soil for 24 hours: 27.ix.67.

input as calculated from the partitioning of available energy in the soil by the Bowen ratio. In this table, a dash indicates no evaporation; in those entries marked with an asterisk, the gradient of temperatures was not steep enough for reliable computation. The net radiation ( $R$ ) and heat flux in the ground ( $G$ ) are also given, in milliwatts per square centimetre, the units used in computation (Slatyer & McIlroy 1961). Moisture content of the nest soil at this time was 2.6%.

## DISCUSSION

### NEST TEMPERATURE

The close relationship between net radiation and soil temperature is apparent from Figure 12. The net radiation may be seen as the sum of two components:

(i) There is a more or less steady level of outgoing radiation: the Stefan-Boltzman equation (Rose 1966) shows that all bodies emit radiation with a flux density proportional to their absolute temperature, i.e. about  $300^{\circ}\text{C}$ . As the absolute temperature fluctuation of the soil surface is relatively small, either on a daily or yearly basis (and the difference between nest and soil temperature even less), the variation in this component of the radiation equation can be taken as negligible. This may be seen in Figure 12, between 2200 and 0400 hours when there is no incoming radiation. Similarly, Wien's displacement law predicts that the wavelength of maximum emission of this radiation (which is also proportional to the absolute temperature) will be in the long-wave infra-red region of the spectrum, at about 10 microns.

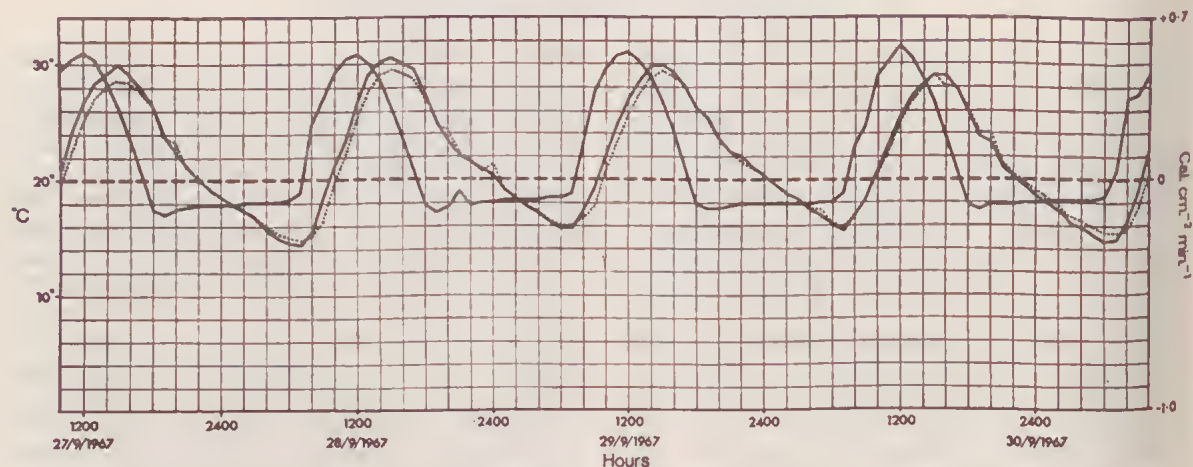


FIG. 12—South Ita Sandhills—net radiation (right ordinate) and average temperature (left ordinate) of nest (solid line) and adjoining soil (broken line): 27-30.ix.67.



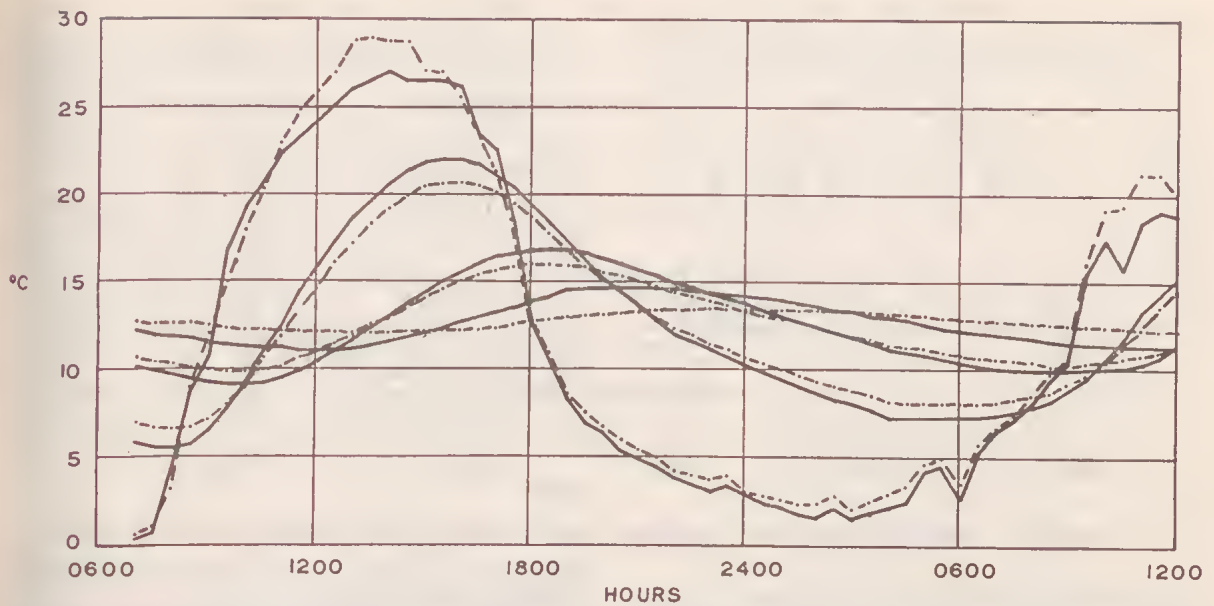


FIG. 13—South Ita Sandhills—surface, 10, 20 and 40 cm temperatures of the nest (solid line) and adjoining soil (broken line): 13-14.viii.68.

(ii) The incoming, short-wave radiation from the sun reaches the surface after attenuation by reflection and scattering in the atmosphere; this component consists of this direct beam of radiation and an indirect quantity known as sky radiation. The radiation impinging on a surface such as the soil is subject to reflection from that surface, and part of the incoming radiation is lost back to the sky—the reflection co-efficient is termed the albedo. Finally, the flux density falling on a horizontal surface is attenuated by a factor equal to the cosine of the angle of elevation of the sun. The resultant flux density measured by a horizontal radiometer is thus a smooth curve, subject to modification by events such as passing clouds or other changes in the optical properties of the atmosphere.

Radiation absorbed by the nest or soil surface causes a rise in temperature. If the soil below is cooler, some of the heat will be conducted downward to successively lower levels in the soil, and the deeper ground temperatures will rise. At the same time, part of this energy is lost from the ground to the atmosphere by sensible and latent fluxes: that is in warming the air above the nest and in evaporating soil water. Thus the temperature attained at any point is the result of the balance struck between heat input, either radiative or conductive, and losses.

Radiative energy input reaches its maximum (on a clear day) when the sun reaches the zenith, at which time the surface temperature is also at

or approaching its maximum. After this, the surface temperature begins to drop, but energy is still being transferred down the temperature gradient into the soil; the maximum temperature attained at any depth becomes lower and occurs later as the depth increases (Fig. 2-5). This process is seen most clearly in Figs. 10 & 11; the line cutting across the isotherms, joining their deepest points, is a measure of the speed of transmission of heat through the soil: it is curved, rather than the straight line expected, because the soil is not homogeneous in its heat transmission characteristics.

When the surface becomes cooler than the deeper levels at night, the direction of heat flow is reversed. This is apparent from Fig. 14, which shows the net radiation of the nest (the greater amplitude curve) and the soil heat flux. Heat flowed into the nest from 0845 in the morning until 1730 in the afternoon, after which stored energy started to pass back to the surface. Two additional points of interest arise from this figure. Between 0300 and 0400 in the morning, the radiation loss quite suddenly decreased. This coincided with the arrival of a meteorological frontal system; observations recorded at the time show no cloud until 0300, when 1/8 cloud cover was recorded in the southwest, 4/8 at 0330 and 7/8 at 0430, which continued, with a short break at 1600, for the remainder of the period. The clear sky is an acceptor of long wave radiation, whereas cloud reflects back a considerable part.

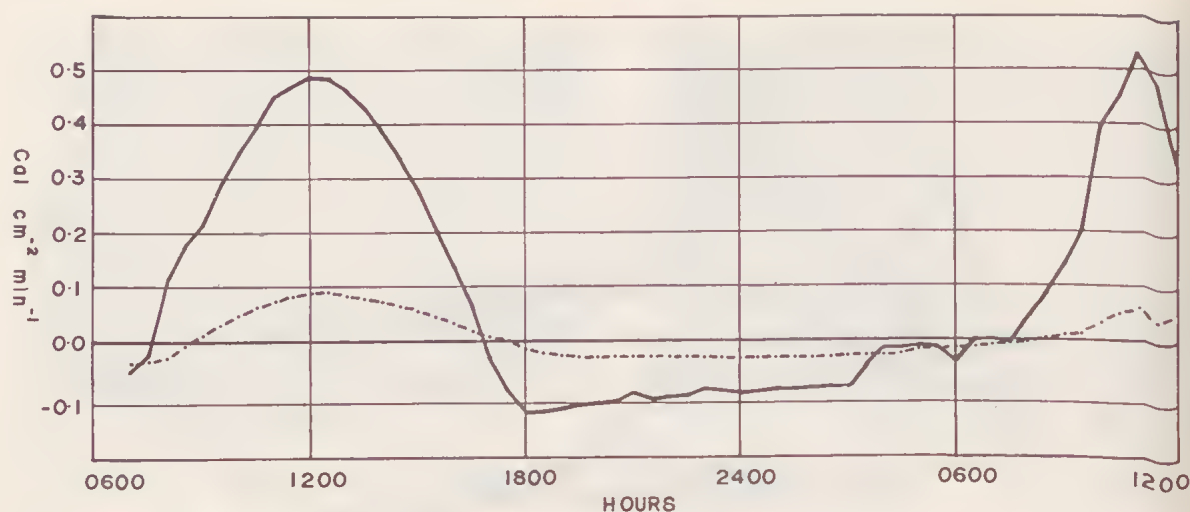


FIG. 14—South Ita Sandhills—net radiation (solid line) and soil heat flux over 30-hour period: 13-14.viii.68.

Integration of the soil heat flux curve (Fig. 14) shows that in this period,  $27.73 \text{ cal cm}^{-2}$  passed down through the flux plates, but only  $22.56 \text{ cal cm}^{-2}$  passed up. The difference,  $5.17$  calories, means that the temperature at this level,  $5 \text{ cm}$  below the surface, should be  $3.04^\circ\text{C}$  higher on 14.viii.68 than on the previous day (calculated from the experimentally obtained thermal capacity). Interpolating from the temperatures at the surface and  $10 \text{ cm}$  (Fig. 13) the observed temperature difference is  $3.03^\circ\text{C}$ .

It will be seen that the ants have, at most times, levels in the nest at which the temperature should be satisfactory for their various functions: higher temperatures for incubating brood near the surface in the day, and a warm zone lower in the nest at night. Most of the galleries are clustered in the upper  $25 \text{ cm}$  of the nest, so it would appear that this region is satisfactory for their activities. Below  $25 \text{ cm}$ , the nest consists of a relatively few deep shafts with occasional side galleries, in which most of the population is to be found during cold winter conditions (Ettershank 1968). This author also estimated that the galleries occupy 8-10% of the volume of the upper part of the nest; as the heat input to the nest and to the surrounding soil is the same, it would be expected that the temperature rise in the nest would be about 10% more, and this can be seen in Fig. 2-5, & Fig. 13. Note also that the deep temperature in the nest is above that in the soil, a positive benefit for the occupants. The expected, more rapid rate of heating in the nest can also be observed. However, the nest surface is cooler during the day (Fig. 13); this is discussed below in reference to the nest surface and decoration.

## SOIL MOISTURE

The three large sampling trials conducted showed higher soil-water levels in the nest than in the surrounding soil (Table 2).

Rates of water loss, calculated from the energy data and the Bowen ratio, apply to large areas, not local patches (Slatyer & McIlroy 1961). Water loss from a surface depends on there being a source of heat to supply the latent heat of vaporization ( $590 \text{ cal gm}^{-1}$ ); on the vapour pressure of the overlying air being maintained at less than that of the evaporating surface (that is, water vapour, like heat, must pass down a gradient, since evaporation is a net transfer of water molecules); and finally, there must be a continuing supply of water available for evaporation, and so drier soils impose a limiting factor (Rose, 1966). Generally, evaporation can be expected to continue while energy is available, i.e. when  $R - G$  (Table 3) is positive. Evaporation did take place over much of the day, but not in the middle of the day, presumably because all the available water had been removed and a recovery period was necessary. This effect was observed on the five other days for which partial records were collected.  $R - G$  may be positive at night, but then no vapour gradient may be present. It should be noted that the accuracy of these energy balance computations are dependent on a reasonable vertical gradient between the measuring sites. Slatyer & McIlroy (1961) suggested as a rule of thumb that the gradient should be twenty times the accuracy of the measuring instrument, which in this case would thus be  $1^\circ\text{C}$ . Also, the model was developed initially for free water surfaces,

TABLE 1

SOUTH ITA SANDHILLS—selected Air and Surface Temperatures 14/viii/68 (see text)

Time	10 cm Air Temperatures (°C)		Surface Temperatures (°C)	
	Dry bulb	Wet bulb	Nest	Soil
0030	0.70	0.52	2.30	2.70
0100	0.90	0.55	2.22	2.66
0200	0.10	0.10	1.55	2.30
0300	0.10	0.10	1.31	1.97
0330	0.25	0.25	1.78	2.25
0400	1.01	1.01	2.04	2.69
0430	1.64	1.62	2.52	3.20
0500	3.27	2.95	4.14	4.53

TABLE 2

SOUTH ITA SANDHILLS—mean percentage water content of nest and soil samples at three sites (64 samples from each site); number of samples from nest and soil at each site is shown in brackets.

Site	Nest	Soil	Significance
1	2.1% (20)	1.9% (44)	*
2	1.3% (14)	1.1% (50)	*
3	3.4% (23)	3.1% (41)	*
Overall Averages	2.3%	2.0%	

and only later applied to agricultural problems. In consequence, investigations of the model, in which the calculated losses were checked against a lysimeter, have been restricted to soils with a higher water status, and its application to drier soils, though satisfactory in theory, has not been rigorously tested.

Air movements parallel to the ground surface in such sparsely vegetated areas ensure that conditions over any area are fairly uniform, that is that there will not be small pockets with abnormally high or low temperatures or humidities. The figures quoted in Table 3 should be an unbiased estimate of conditions over much of the surrounding countryside. At ground level, however, it can be seen from Figure 13 that the nest surface temperatures are below those of the surrounding soil. A sample of these data, for 13.viii.68, is shown in Table 1. From these, it will be seen that for three hours in the early morning the air at 10 cm is at dew point; this is a regular feature of desert environments. Dew tends to impinge on the coolest objects in an area and on slightly elevated objects (Slatyer & McIlroy, 1961), and the surface of the nest fulfils both these qualifi-

TABLE 3

SOUTH ITA SANDHILLS—radiant and soil heat fluxes, and calculated evaporation rate.

Date	Time	R mW cm <sup>-2</sup>	G mW cm <sup>-2</sup>	E mm H <sub>2</sub> O day <sup>-1</sup>
13.viii.68	0800	7.99	-4.10	—
	0900	14.74	1.61	8.1
	1000	24.25	6.41	30.7
	1100	31.41	9.16	4.2
	1200	33.97	12.22	—
	1300	32.26	11.26	—
	1400	27.24	10.24	0.4
	1500	19.34	7.28	0.8
	1600	9.42	4.54	1.1
	1700	-2.23	0.52	—
	1800	-9.51	-2.28	— *
	1900	-8.82	-3.93	— *
	2400	-6.57	-4.76	— *
14.viii.68	0400	-2.22	-3.82	— *
	0500	-1.55	-2.61	— *
	0600	-3.74	-3.05	— *
	0700	0.00	-1.11	— *
	0800	2.95	-0.32	2.2
	0900	4.80	0.92	4.6
	1000	27.46	4.86	—

cations. If, as is likely, the air flow at the surface is at the same temperature as the general soil surface and the air is saturated (Geiger, 1965), then the surface of the nest will be below dew-point and dew will immediately form on it. The nest soil would rapidly absorb it, reducing the chance of re-evaporation.

Now, most of the water 'falling' as dew does not come from any height in the atmosphere, but instead from distillation from the ground, and thus generally speaking there is little or no overall gain from dewfall over any large area (Geiger, loc. cit.). In this case, however, it is proposed that the nest is gaining dew at the expense of the surrounding area. Slatyer & McIlroy show on theoretical grounds that the maximum possible rate of condensation would be 0.07 to 0.15 mm hr<sup>-1</sup>, and state that the maximum reliably recorded rate of dewfall for one night was 0.5 mm, although the conditions were not given. If the nest does act as a focus of condensation, input locally could be higher. The gradient of soil moisture in the nest was not studied, but it can readily be calculated that to maintain the higher water status observed in a 25 cm column of nest material



would require an input differential to the nest of 0.75 mm of dew per  $\text{cm}^2$  per night. Some form of lysimeter would be needed to demonstrate this model, and this would hardly be practical in an ant nest.

Diem (1937) has shown experimentally that sandy soils 'breathe' a volume of air each day equivalent to a column 22 m high; Geiger (1965) points out the importance of the water in this transpired air. Moist atmospheric air will give up moisture to the soil if this is colder, and he terms this 'internal dew'. For the nest to gain the 0.3% differential observed, it would also have to absorb the latent heat of vaporization of the water, amounting in this case to 44 calories  $\text{cm}^{-2}$ , which would give a 5°C rise in the 25 cm column of soil if it were all released at once. Over a period of some hours, of course, the effect would hardly be visible in the overall heat economy of the nest.

Chaptal (1932), in a little-noticed paper, showed that viticultural soils in the south of France gained 2000  $\text{m}^3$  of water per hectare more than could be accounted for by rainfall or movement of soil water, and showed that this was probably acquired by adsorption of water molecules to the soil in a similar process of soil transpiration. He was able to show, furthermore, that much of this fixation of water by the soil occurred between 2 p.m. and 6 a.m. when the subsurface soil was warmer than the air, so this was not simple condensation of dew. It is interesting that the surface of the meat ant nest is perforated with entrance holes, the content of coarse sand is increased compared with the surrounding soil (Ettershank, 1968) and the bulk density may be slightly lower (possibly due to working by the ants), all of which should increase ventilation and fixation of water.

On a much larger scale, Chaptal discussed the report of a group of engineers who found that certain natural springs result from condensation inside severely fissured geological formations overlying an impervious bedrock. He quotes a communication to the French Agricultural Academy from a H. Hitier on the investigation of the 13 'aerial wells' of the ancient Greek settlement of Theodosia, in the Crimea, which consisted of pyramids of calcareous stones measuring  $30 \times 25 \times 10$  metres. Conduits from these to the town are claimed to have supplied 720  $\text{m}^3$  of potable water per day. Chaptal describes a model of these that he built, which delivered a maximum of 2.528 litres per day.

Winterkorn (1955) found that a similar phenomenon was responsible for swelling and buckling of some road foundations.

## SOIL HUMIDITY

Air in the galleries is presumably in equilibrium with the soil, and shows a fairly constant value around 68% (confirmed for a nearby locality by D. Shorthouse, pers. comm.).

## NEST METABOLISM

Gas analysis of air aspirated from the nest shows that the ants breathe air somewhat depleted of oxygen ( $-0.217\%$ ) and enriched with carbon dioxide ( $+0.15\%$  or 4.5 times the level in free air) as shown above. No work has been done on the physiological response of ants to high levels of carbon dioxide; the usual response in insects is to open the spiracles through relaxation of the spiracular closing muscles, an endogenous property of this muscle in the presence of high levels of dissolved carbon dioxide (Wigglesworth, 1965). This would seem inappropriate in an animal that normally lives under such conditions, particularly as the relative humidity in the nest is only 68%, but the action of the spiracular occluder cannot be seen from the outside on an intact ant, so this is not easily studied.

Two methods were used to check the fidelity of the respirometer hood method. Firstly, oxygen absorbent was injected into the soil under a hood on the ground to a depth of 10 cm; at the same time an equal volume of absorbent was injected into a 250 ml flask fitted with a horizontal burette partly filled with an indicator fluid. In two trials 8.25 ml of oxygen was absorbed in the flask when 8.64 was accounted for in the air sample drawn from the hood during 25 minutes; for the second trial, the corresponding figures are 6.60 and 6.51. Secondly, carbon dioxide levels under the hood could be checked against the observed, laboratory determined respiratory quotient of 0.78 (Cutress and Ettershank, unpublished data). At 20°C, the oxygen consumption calculated from the regression line is 21.23  $\text{mm}^3 \text{cm}^{-2}$ , for which the predicted carbon dioxide production is 16.30  $\text{mm}^3$  and from the RQ is 16.56  $\text{mm}^3$ . The correspondence is not as good at lower temperatures, possibly due to slower diffusion of the carbon dioxide.

Whether the nest can be used as a natural calorimeter (Englemann, 1966) can be answered from the respirometry data. At the respiratory quotient of 0.78, one cubic centimetre of oxygen consumed in metabolism releases 4.73 calories of heat (Southwood, 1966), so 18  $\text{mm}^3 \text{cm}^{-2} \text{hr}^{-1}$  represents 0.086 cal  $\text{cm}^{-2} \text{hr}^{-1}$ . (Note that Southwood (1966) drew the data for this table from the classical book by Brody (1945), as have many authors since. Now Brody adopted a convention: 'calories' meant the normal CGS unit, but 'Calories' meant kilocalories. Southwood ap-

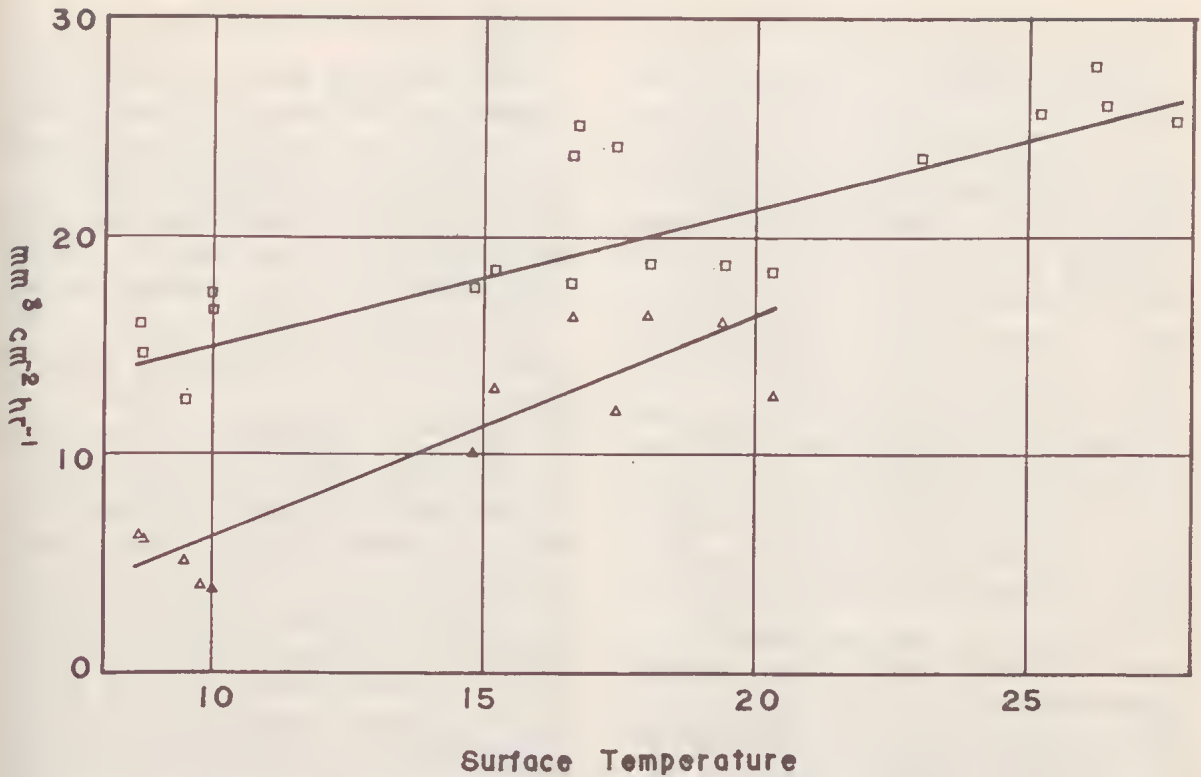


FIG. 15—South Ita Sandhills—oxygen consumption (squares) and carbon dioxide production (triangles) of a meat ant nest, against temperature. Equations to the lines are  $Y_{O_2} = 8.60 + 0.63X$  and  $Y_{CO_2} = -3.77 + 1.00X$ , where  $X$  = temperature in °C.

parently missed this, so that his figures are wrong by a factor of 1000.) With a thermal capacity of  $0.34 \text{ cal cm}^{-3} \text{ deg C}^{-1}$ , this would raise the temperature of one cubic centimetre of soil by  $0.25^\circ\text{C}$  per hour. With the present probe spacing, this would not be detected, and in any event, changes of this magnitude could easily be swamped out by the perturbation of a passing cloud. Thus this approach is considered to hold little promise.

Using the respirometry data, an estimate of the overall metabolic activity of the nest may be obtained. The surface area of the nest is  $4.93 \text{ m}^2$ , so the overall oxygen consumption at  $20^\circ\text{C}$  is  $1.047 \text{ l hr}^{-1}$ . This is equivalent (Southwood, 1966) to the production of 5 kilocalories per hour; to achieve this, the occupants of the nest would need to metabolize 1.35 grams of glucose, 0.87 g of erude protein or 0.53 g of fat. At  $10^\circ\text{C}$ , the oxygen consumption would be 0.701, producing 3.3 Keal per hour, for which the respective substrate equivalents are 0.90 g, 0.58 g and 0.35 g.

Ettershank (in press) found that this ant consumed  $1.66 \text{ ml O}_2$  per 100 mg dry weight per day at  $21^\circ\text{C}$ . Thus the above data would indicate 1.5

of dry weight of ants in the nest or 4.5 kg wet weight, or about 300,000 individual ants. This is of the same order of magnitude of an estimate based on data by Greaves (pers. comm.) from excavation and counting of nests in the Canberra area, allowing for the larger size of the ants at South Ita.

Ettershank (in press) also found, using a miniature bomb calorimeter, that the meat ant was equivalent to some  $5.5 \text{ Keal gm}^{-1}$  dry weight; thus the standing crop of meat ants in the nest is excavation and counting of nests in the Can-estimated at 8250 Keal.

#### NEST SURFACE

The most striking feature of meat ant nests is the 'decoration' of the surface, noted by every author who writes about this species. Small pebbles, and particularly ironstone soil nodules, measuring 2 to 4 mm seem to be the preferred material for covering the nest, particularly around the coast and in the mountains; on the inland slopes leading back from the Great Dividing Range, pebble decoration slowly gives way to use of plant parts together with a greater or lesser amount of pebble: small twigs, leaf petioles,



gumnuts and chopped-up grass stems are all used (Ettershank, 1968).

On one nest observed by the present author at Nyngan, N.S.W., on an extensive silt plain where no pebbles could be found, and plant fragments seemed sparse also, the ants had acquired the broken-up crust formed by the action of rain on the surface of the soil, and arranged these pieces over the surface of the nest. At all times when the workers are active, some may be found re-arranging the decoration on the nest, moving pieces so that the distribution appears to the human eye to be very regular. Many returning workers carry pebbles or plant parts.

The decoration would appear to fulfil a number of functions, which are listed below. Whether any particular one was the object of intense selection during the evolution of this nest form (seen also in desert species in North America) can only be speculation; of the four, however, mechanical protection would seem the most basic. The suggested functions are:

(i) The decorated area differentiates a behavioural boundary: large vertebrate intruders onto the nest area are pursued and attacked vigorously by the workers, but outside the decorated area, the intensity of pursuit diminishes sharply, and few workers will persist in following the intruder a metre from the nest area. Attackers attached to the intruder continue to bite, however, until mechanically removed. The ground-level attack, incidentally, is visually oriented, for the attacking phalanx of workers will follow any large object after being provoked.

(ii) The decoration protects the surface from rain erosion. The ants build up collars around the entrance holes *before* storms, and narrow the entrances down until only a single ant can pass through at a time; decoration material is often moved onto these collars. As soon as the sun starts to shine after a heavy downpour, the collars are removed and the entrance holes are opened up to 1.5 to 2 cm. If gravel is removed from a nest during a severe rain-storm, rain erosion may be seen and occasionally gallery roofs are breached.

(iii) By presenting an aerodynamically 'rough' surface, the decoration causes turbulence and prevents laminar air flow over the nest surface, which would reduce the rate of heat transfer by several orders of magnitude (Rose, 1966; Slatyer & Mellroy, 1961). In Fig. 13, it is apparent that the immediate surface layer of the nest is cooler than that of the adjoining soil, although at all levels below ground the nest is warmer; this must be attributed to turbulent cooling at the surface. It is notable that at night the nest surface temperature

parallels the soil surface temperature, but is 0.5 to 1.0°C cooler.

On the other hand, a heavy gravel covering is found in areas with lower daytime temperatures. The gravel, having a lower thermal capacity, heats more rapidly than would an exposed soil thereby creating a sharper gradient into the soil; the upper temperature reached is still about the same, but the heating curve is steeper, giving the colony a longer period each day on a more favourable temperature regime.

(iv) The decorative fragments would present a greater area for dew deposition, as discussed above.

Finally, there is a seeming paradox in a desert ant constructing a mound nest, which will receive greater insolation (Steiner, 1929) and increase the heat burden of the colony in summer. It is distinctly advantageous in cold areas, and higher mounds are seen in mountain areas (Greaves, 1939). For the desert ant, it may be advantageous in winter, when the heating curve, at least of the eastern side of the nest, will be steeper allowing activity and foraging to start a little earlier, but ants deeper in the nest would already be at 'working temperature', and any advantage would be lost as soon as the ant leaves the surface of the nest. Other ant species excavate quite large nests and dispose of the spoil—the meat ant actually brings in extra material and incorporates it into the nest. This paradox is elucidated if the functions of the mound discussed above are accorded to it: that it acts as a focus for dew deposition and as a surface for heat dissipation through turbulent cooling. Paradoxes in biology are usually in the mind of the observer: evolution does not lead to insoluble enigmas.

## CONCLUSIONS

1. The use of a net radiometer, soil heat flux plates and thermistor thermometer probes enables a close study of the temperature regime in an ant nest; the fate of incident solar heat can be followed and quantitatively accounted for when other soil parameters (such as thermal capacity) have been obtained. Partition of the heat budget allows estimates of the rate of water loss from the soil.

2. The nest passes through a cycle of heating and cooling each day; temperature excursions are greatest at the surface, decreasing with depth. This cycle is modified by the nest structure compared with the soil nearby, and all levels show slightly greater excursions, except the surface which benefits from turbulent cooling.

3. Soil moisture is slightly higher in the nest, and it is suggested that this is maintained through



differential capture of dew, at the expense of the surrounding soil.

4. The relative humidity of the air in the nest is similar to that in the surrounding soil—despite the higher nest temperature—at around 68%.

5. Ants in the nest live in an atmosphere enriched some 4.5 times with carbon dioxide and slightly depleted of oxygen.

6. Collection of gases in a hood over the nest gave a measure of the overall respiration. From this data, it is concluded that temperature measurements of the nest, treating it as a natural calorimeter, could not be used to estimate respiration. Energy consumed in respiration was found from gas analysis to be 5 Keal  $\text{hr}^{-1}$  for a 4.9  $\text{m}^2$  nest at 20°C and 3.3 Keal  $\text{hr}^{-1}$  at 10°C.

7. As the respiration rate per ant was known, the population was estimated to be 1.5 kg dry weight, or about 300,000 individual ants, equivalent to 8250 Keal standing crop in the nest.

8. The 'decoration' on the nest was found or presumed to subserve several functions: a behavioural boundary, a mechanical protection, a modifier of surface temperature and a dew trap.

9. The logical dilemma of reengineering a heat-gathering mound nest with a desert environment is solved by examining the advantages accruing from this type of construction.

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## THE DISAPPEARING MITCHELL DELTA

By E. C. F. BIRD\* & N. J. ROSENGREN\*

**ABSTRACT:** Maps compiled from surveys of 1848-49, air photographs of 1940, and the present (1970) configuration show that the Mitchell River silt jetties, protruding into Lake King, have now been reduced to little more than half the area they had attained 120 years ago, as the result of shoreline erosion following die-back of a former reedswamp fringe. They will disintegrate and disappear completely within the next 50-100 years if erosion continues at the present rate. Factors influencing shoreline erosion include the wave regime, the extent of weed growth (*Zostera* spp.), the presence of driftwood, the effects of grazing stock, and the accumulation of sandy beaches. Shore protection schemes, applied piecemeal, have so far been generally unsuccessful, but in view of the scientific interest and recreational value of the silt jetties, conservation measures (such as the building of rubble walls) are advocated.

### INTRODUCTION

The deltaic silt jetties built by the Mitchell River into Lake King, one of the Gippsland Lakes, are unusual landforms, the origin of which has been the subject of much discussion (Bird 1970). When they were first mapped, in the years 1848-49, they had a cover of scrub vegetation (mainly *Melaleuca ericifolia*) with occasional red gums, and were fringed by marshland with reedswamp (mainly *Phragmites*) spreading out into the bordering lakes. The reedswamp trapped silt and clay brought down by the river during floods in such a way as to build up and extend the delta shoreline; it also served to protect the shoreline from wave attack. The fringe of reedswamp persisted until the early years of the present century, for it was observed by Gregory (1903) during his visit to the Gippsland Lakes in 1901, but by the nineteen-twenties it had largely disappeared.

The loss of the reedswamp fringe has been attributed largely to salinity increase in Lake King following the cutting of an artificial entrance to the Gippsland Lakes in 1889 (Bird 1961, 1962, 1965). Grazing of the reedswamp by cattle when the delta was cleared of scrub and converted to pastureland also contributed to the disappearance of *Phragmites*, but lake salinity is the critical factor because the reeds have also vanished from sectors beyond the reach of cattle grazing, and have failed to reappear on sectors that are no longer grazed. In the absence of the protective

reedswamp fringe, the shorelines of the silt jetties have been attacked by wave action. The Mitchell delta is thus being consumed by erosion: it provides a good illustration of the indirect and unforeseen consequences that may result from man's interference with a natural system (Jennings 1965).

### HISTORICAL EVIDENCE

The pattern and rate of reduction of the silt jetties can be determined with reference to old map and air photographs. The first survey of the southern (Eagle Point Bay) shoreline was made by George Smythe, and is shown on his Coast Survey Plan No. 4. The original map, kept in the Central Plan Office of the Victorian Department of Lands is undated, but is one of a series compiled during the years 1846-51, and probably dates from 1848. The first survey of the northern (Jones Bay) shoreline was made by John Wilkinson in 1849, and is shown on his Gippsland Plan No. 6, also kept in the Central Plan Office of the Department of Lands. The two outlines have been combined in Fig. 1 to show the configuration of the Mitchell delta in 1848-49 as a basis for comparison with the outline shown on air photographs taken in February 1940 and with the present (February 1970) outline.

Caution is necessary when using old maps to determine past landform configuration (Carr 1962). There may have been errors or technical

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limitations in the original survey work or in its cartographic reproduction, and there is the possibility that a map has shrunk, or been stretched, during its storage over a long period. Scales and directions have been checked on the two historical maps and in the original field books, and measurements between identifiable fixed points indicate shrinkage of the order of 3% on Wilkinson's plan. The outlines must therefore be regarded as approximate, but it is possible to make a rough estimate of the extent of the Mitchell silt jetties, downstream from Eagle Point, from the 1848-49 surveys. Such an estimate is based on outlines which include the reedswamp fringe, extending from an inner margin of usually dry land to an outer limit where the lake is up to 5 ft deep. In these terms, the northern silt jetty had an area of 15.11 million sq ft and the southern jetty an area of 13.50 million sq ft in 1848-49.

Further growth of the silt jetties probably took place during the second half of the nineteenth century, but it is difficult to find reliable evidence of this. A parish plan dated 1873 is little more than a rough sketch map, almost certainly inaccurate in showing the southern silt jetty as extending almost half a mile beyond the end of the northern silt jetty, but another parish plan, surveyed in 1893, shows measured widths along boundaries of subdivisions, and is more likely to be accurate in portraying the shoreline. The 1893 outline is in fact very close to that of 1848, the chief difference being that the eastern part of the southern silt jetty appears slightly wider in 1848.

After 1901, as has been indicated, the reedswamp fringe disappeared and shoreline erosion began; by the early nineteen-twenties there was obvious erosion on the delta shoreline (Hart 1922). By 1940, when air photographs were taken by the Royal Australian Air Force, major changes had taken place. A breach known as The Cut (Pl. 2, fig. 1) had formed in the northern silt jetty downstream from Eagle Point Bluff during a 1919 river flood, and a small area of new deltaic terrain had developed outside it, protruding into Jones Bay. With this minor exception, the northern shoreline, relatively simple in outline in 1849, had retreated and become embayed in 1940. This was partly due to the loss of the reedswamp fringe shown on Wilkinson's map. The large embayment immediately W. of Point Lardner was occupied by reedswamp in 1849, and with the disappearance of this the shoreline had retreated by as much as 950 ft by 1940. The extent of recession of the northern shoreline was generally between 50 and 400 ft during 1849-1940, and near the eastern end the northern silt jetty had been breached by shoreline erosion, isolating a small

terminal island. If allowance is made for the readier removal of former reedswamp areas, it is seen that sectors of shoreline facing north-westwards have receded farther than those that faced north-eastwards. This is consistent with the predominance of wave action generated by prevailing westerly winds in Jones Bay. There had also been slight recession along the river banks, but this is too small to be shown on Fig. 1. Overall, by 1940, the area of the northern silt jetty had been reduced to 56.5% of its 1849 extent (Table 1).

TABLE 1  
AREA OF MITCHELL RIVER SILT JETTIES DOWN-  
STREAM FROM EAGLE POINT BLUFF

	(million sq ft)		
	1848-49	1940	1970
Northern jetty	15.11	8.55	6.92
Southern jetty	13.50	10.64	8.65

The Eagle Point Bay shoreline of the southern silt jetty had an embayed configuration in 1848, and in 1940 this was still so, W. of Point Foster, though farther E. the shoreline had become straighter as it receded. At Point Foster, and on sectors farther E., the shoreline had retreated about 200 ft. As the outline in 1893 was essentially similar to that of 1848, most of this recession had taken place within 47 years. Recession was greater on sectors exposed to the predominant S.-W. waves in Eagle Point Bay, especially E. of Point Foster, where the south-westerly fetch lengthens and there is deeper water offshore. Also, the general level of the silt jetties declines eastwards, so that removal of a similar volume of material produces greater shoreline recession in the eastern half. Overall, by 1940, the area of the southern silt jetty had been reduced to 79.3% of its 1848 extent. The greater percentage reduction on the northern silt jetty, compared with the southern, is due partly to the formation of The Cut, but mainly to the fact that the reedswamp fringe which had died away was generally broader on the northern than the southern shoreline.

The third outline shown on Fig. 1 is based on measurements made in February 1970, correcting earlier surveys, including one based on air photographs taken in March 1966. It shows that the earlier trends have continued over the past thirty years. On the Jones Bay shoreline there has been further recession of up to 150 ft, and two new breaches have been formed near the eastern end of the northern silt jetty on sectors that were very narrow in 1940. Another breach appears imminent south of Point Lardner, where the minimum width of the northern silt jetty is now only 48 ft (Plate 2, fig. 2). The Eagle Point Bay shoreline has receded up to 250 ft, and the breach

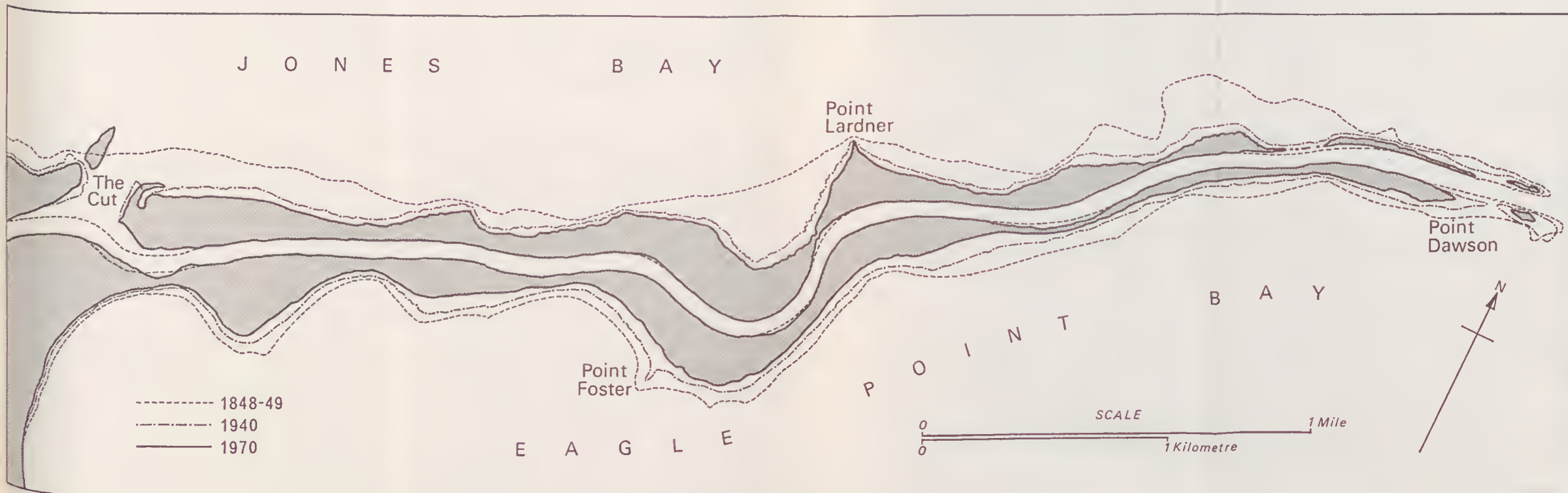


FIG. 1—The past and present configuration of the Mitchell River silt jetties.

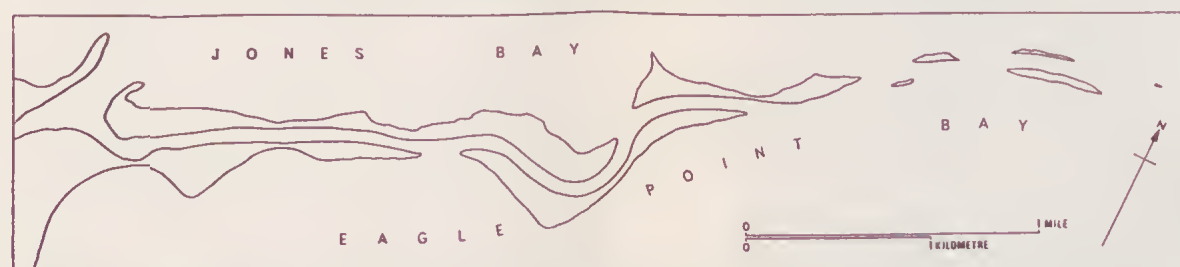


FIG. 2—Configuration of the Mitchell River silt jetties in the year 2000 if erosion continues at its present rate.

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near the eastern end of the southern silt jetty is now much broader than it was in 1940. A section of the southern silt jetty a mile downstream from Point Foster was only 60 ft wide in 1940, and would probably have been breached by now but for the construction of protective shoreline works by the Ports and Harbors Branch of the Public Works Department in 1962, when the width had been reduced to 28 ft (Pl. 2, fig. 3 and Pl. 3, fig. 1). There has been further growth of the deltaic area at The Cut, extending into Jones Bay, but during the past thirty years when erosion has been predominant, the area of the northern silt jetty has been reduced by 19.1% and that of the southern silt jetty by 18.7%.

The second set of figures (1940-70) may be used as a basis for prediction. If this rate of areal reduction is maintained, the northern silt jetty will be completely removed within 128 years and the southern within 130 years. Alternatively, if the lake shorelines retreat as much in the next thirty years as they have since 1940, considerable disintegration will have taken place by the year 2000 (Fig. 2). The northern silt jetty will have at least two new breaches, one W. of Point Lardner, the other farther E., and the southern silt jetty will have been breached just W. of Point Foster, and will have a broad gap farther E., leaving the fishing village at Point Dawson on a shrunken islet. As the formation and broadening of such breaches increases exposure to wave action (enabling waves from Eagle Point Bay to attack the northern bank of the river for instance) the rate of reduction is likely to accelerate, and the life span of the remaining silt jetties will be correspondingly shortened. Taking this into account, it is estimated that, if present conditions persist and if successful shoreline protection schemes are not introduced, the Mitchell River silt jetties downstream from Eagle Point Bluff will disappear within the next 50-100 years.

## PROCESSES OF SHORELINE EROSION

Recession of the lake shoreline of the Mitchell delta is due primarily to wave action. When the silt jetties had a protective fringe of reedswamp, wave action was impeded and the shoreline advanced by sedimentation in the sheltered reedswamp environment. There is now very little *Phragmites* on the Mitchell delta, even on the new deltaic area outside The Cut (Pl. 2, fig. 1). It grows sporadically along the river banks, and there are small clones near the eastern end of the silt jetties, but these are no longer spreading into the lake; in general they are growing up on the delta, behind the eroding shoreline. Once the reedswamp fringe had been lost, waves began to

attack the unprotected shoreline, and now there are receding cliffs of silty alluvium, often with salt marsh vegetation on the margins splashed by brackish lake water. The silt jetties slope away from the river banks to the lake shore, so that generally the height of these bordering cliffs increases as they are cut back. In embayments on the southern shoreline W. of Point Foster they are up to 4 ft high (Pl. 3, fig. 2). On sectors of the northern shoreline where *Melaleuca ericifolia* scrub is no longer protected by a reedswamp fringe, large slabs of root-bound material undercut by wave action calve off and fall into the lake (Pl. 3, fig. 3).

The vigour of wave attack is related to the lengths of fetch and to the direction and strength of winds blowing over the adjacent lake. When the prevailing westerly winds are blowing, water level in the eastern part of the Gippsland Lakes may rise more than 1 ft above calm weather level, whereas easterly winds lower the level of Lake King, exposing abrasion ramps cut in silty alluvium in front of the receding cliffs of the deltaic shoreline. Westerly winds therefore produce larger and more effective waves breaking on the deltaic shoreline, and this is when most of the erosion takes place. Local residents report that parts of the southern shoreline were cut back 4 to 6 ft in a few hours during a westerly gale in 1968. By contrast, strong easterly winds blowing over a lowered lake surface produce little shoreline erosion. The level of Lake King may also be raised by high river discharge (it rose more than 5 ft during the 1952 floods) and under these conditions wave attack can be vigorous, and considerable scour takes place as the result of current action in the river channel. Waves produced by motor boats have also contributed to undercutting and erosion of the channel bank (Pl. 4, fig. 1).

Another factor influencing the vigour of wave attack is the extent of water weed (chiefly *Zostera* spp.) in Lake King. This has fluctuated over recent decades. During the nineteen-fifties, weed growth was sparse but in 1961 *Zostera* began to spread, and it has since remained extensive in water up to 6 ft deep. Earlier fluctuations of weed growth have been reported: Bury (1954) recalled that in 1920 weed growth, which has been prolific, disappeared from Lake King. The reasons for these fluctuations are not known. It is possible that *Zostera* grows better when the lake becomes relatively saline after a series of dry years, and that freshening of the lake by river flooding (which last occurred on a large scale in 1952) is unfavourable for its growth. Infestations of the crab *Paragrapsus gaimardii* are apparently correlated with depletion of *Zostera*, but it is not yet clear

whether the activities of erabs impede *Zostera* growth or whether they invade the lake only when *Zostera* growth is poor. Whatever the explanation the presence of weed in shallow water (Pl. 3, fig. 4) reduces wave action, and the seasonal accumulation of dead *Zostera* leaves on the shore has a slight protective effect. Erosion has still continued, however, in the years since *Zostera* returned to the lake waters bordering the silt jetties.

Large quantities of driftwood, especially branches and trunks of dead willow trees, are washed down the Mitchell and out through The Cut into Jones Bay. The northern shoreline of the silt jetties has extensive accumulations of driftwood which, seen on a calm day, might be regarded as having a protective influence (Pl. 4, fig. 2). This, however, is not so. The driftwood lodged against the shoreline in shallow water is moved to and fro, even by gentle wave action, and then has a scouring effect on the soft sediments of the silt jetties. Individual logs agitated by wave action can have the effect of a battering ram (Pl. 4, fig. 3), punching or scraping out coes in the soft alluvial shoreline. One such log was observed to excavate a cove measuring 11 sq ft over a period of 1 year. Sectors of the shoreline strewn with driftwood thus develop an irregular or scalloped outline, and are probably cut back much more rapidly than they would be if driftwood were not present. There is less driftwood on the Eagle Point Bay shoreline, but the same process has been observed locally there.

One way in which shoreline erosion might be expected to come to an end is by accumulation of protective beach material. A sandy beach gives some protection to the shoreline at the western end of Eagle Point Bay, but the beach must be broad if it is to be protective: small quantities of beach material merely arm the waves with abrasive debris and accelerate erosion. Material eroded from the delta shoreline consists largely of silt and clay, which are removed and dispersed into Lake King, but sandy material (derived mainly from the river cliff at Eagle Point Bluff) washed out from the Mitchell River through The Cut has drifted eastwards across the floor of Jones Bay to accumulate as a beach at Point Lardner. At this point, sand has accumulated around driftwood, and once the logs are embedded in the beach they no longer act as agents of shoreline erosion (Pl. 5, fig. 1). On the southern shoreline patches of sand from the beach at Eagle Point Bay have drifted eastwards as far as Point Foster. There is, however, little chance that shoreline erosion will be halted by natural beach accumulation, for these local sources of sandy material are meagre.

## SHORE PROTECTION SCHEMES

Individual landowners have attempted to protect their lake shore frontages from erosion with various kinds of structures, including fencing, brushwood, waste materials and brick or concrete walls, but with little success. The disadvantage of this piecemeal approach is that a protected sector of shoreline is outflanked as erosion proceeds on adjacent unprotected sectors, and wave action eventually penetrates laterally behind shoreline defences.

In the early nineteen-sixties the Soil Conservation Authority and the Ports and Harbour Branch experimented with brushwood and wooden groynes and barriers, but although these temporarily reduced the erosion rate they have now generally fallen into disrepair. (Pl. 5, fig. 2, 3, 4). Attempts have also been made by the Soil Conservation Authority to re-establish shoreline vegetation to take over the protective role of the lost reedswamp. This really requires a robust reed species, tolerant of brackish, almost tideless water, of irregular flooding and occasional strong wave action, and capable of forming a nearshore vegetation fringe. So far, the search for such a species has been unsuccessful: *Paspalum vaginatum* has grown well on sheltered sectors, but it cannot withstand strong wave attack, whereas *Spartina* spp., which grow well on tidal mudflats in Andersons Inlet and elsewhere (Bird and Boston 1968), are unable to spread in this almost tideless environment. The search continues, nevertheless, and there is still a possibility that the efforts of the Soil Conservation Authority will provide an answer, perhaps in the form of a reed species bred to fit these exacting requirements.

*Phragmites* reedswamp would probably revive here and resume its protective role if Lake King were freshened by the insertion of some kind of barrage structure designed to exclude the sea water which enters at Lakes Entrance. However, this raises a number of practical and political difficulties discussed previously (Bird 1966), and it is unlikely that the problem will be solved in this way.

The rate of erosion could be reduced by excluding grazing cattle, removing driftwood from the delta shoreline, and intercepting any more driftwood that is washed down the Mitchell River before it drifts out into Jones Bay. Cattle certainly break down the lake shore cliffs, and grazing reduces the luxuriance of shoreline vegetation; driftwood mobilised by wave action is certainly damaging the northern shoreline. But erosion continues on sectors that have been fenced to exclude cattle (Pl. 5, fig. 4) and on sectors



where driftwood has been removed, or is locally absent, so that even with these measures the delta would gradually disappear. It seems that the only certain way of conserving the Mitchell River silt jetties in their present shrunken form is by building and maintaining solid shoreline walls of wood, rubble stone or concrete. In 1967, the Ports and Harbors Branch of the Public Works Department estimated that the building of rubble stone walls on the present lake shoreline of the silt jetties would cost \$125,000. For this sum, the silt jetties could be preserved as a scientific feature, and a natural pier giving land-borne recreational access to the northern part of Lake King. One consideration which should not be overlooked is that the shoreline length of Lake King will be reduced by about 8 miles (and another 8 miles of river bank will be lost) once the silt jetties have disappeared; a reduction that represents a substantial loss of recreational opportunity in the Gippsland Lakes region. In these terms, the cost of artificially preserving the Mitchell River silt jetties may not be excessive.

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## DESCRIPTION OF PLATES 2-5

## PLATE 2

- FIG. 1—An oblique air photograph of The Cut, showing part of the delta built into Jones Bay. Note driftwood.
- FIG. 2—An oblique air photograph of the Mitchell River silt jetties below Point Foster (bottom left) looking northward to Point Lardner and Jones Bay. Note the narrow sector of the northern silt jetty, where breaching is likely to occur within the next few years.
- FIG. 3—An oblique air photograph of the Mitchell River silt jetties showing the narrow sector of the southern jetty.

## PLATE 3

- FIG. 1—The narrow sector of the southern silt jetty protected by a wooden wall on the lake shoreline.
- FIG. 2—A cliffed sector of the southern shoreline west of Point Foster.
- FIG. 3—An undercut slab of silt, bound by roots of *Melaleuca ericoifolia*, fallen into the lake E. of Point Lardner.
- FIG. 4—*Zostera* growth in shallow water off the southern shoreline.

## PLATE 4

- FIG. 1—Eroded river bank. *Phragmites* sparsely present.
- FIG. 2—A broad zone of driftwood bordering the northern shoreline.
- FIG. 3—A log which is moved to and fro by wave action in such a way as to scour the shoreline.

## PLATE 5

- FIG. 1—The sandy beach at Point Lardner with embedded driftwood.
- FIG. 2—Wooden walls and groynes, now derelict, on the northern shoreline. These have been damaged by driftwood delivered by wave action.
- FIG. 3—Part of the southern shoreline, fenced to exclude cattle grazing, with groyne system (February 1964).
- FIG. 4—The same site in December 1969.













## THE VEGETATION AND ENVIRONMENT OF A MULTI-AGED EUCALYPT FOREST NEAR KINGLAKE WEST, VICTORIA, AUSTRALIA

By A. M. GILL\* and D. H. ASHTON†

**SUMMARY:** A dry sclerophyll forest dominated by *Eucalyptus obliqua* and *E. radiata* (and to a lesser extent, *E. cypellocarpa*) occurs on a mosaic of red and grey soils on the Kinglake Plateau. The red soils are better structured and have slightly higher nutrient status than the grey. The vegetation on both soils is similar on similar topography although differences in species presence and cover occur. The differences may be attributed to a slightly faster rate of succession after fire on the red soil. The range of form and size of the canopy eucalypts suggests diverse ages. Beneath these a definite stratum of suppressed trees occurs, largely composed of *E. radiata*. It is possible that the absence of fire over a long period may favour *E. radiata* predominance and conversely that fire may restore the importance of *E. obliqua* in the stand. The understorey on the red soil has developed a self-perpetuating pattern of *Pultenaea muelleri* clumps together with *Pteridium* (bracken) and *Tetrarrhena juncea* (wiregrass) forty years after firing. Invasion of mature stands by broad-leaved shrubs in the absence of fire could result in a transitional wet sclerophyll forest.

### INTRODUCTION AND SITE DESCRIPTION

Descriptive accounts of the structure and composition of Australian vegetation are rare, yet description yields valuable data on classification, community history, regeneration, and species relationships. This paper attempts a description of a little-disturbed eucalypt forest and its environment.

The area is approximately 40 miles NNE. of Melbourne on the Great Dividing Range at the western edge of the Kinglake Plateau. It extends for one half mile on the southern edge of the Plateau from the Cascades water channel towards Kinglake West.

The climate of this region is warm and relatively wet in summer, and cool and wet in winter. The average precipitation is likely to be similar to that recorded at two nearby weather stations: average approximately 48 inches at Wallaby Creek and 49 inches at Kinglake (Watt 1937). Precipitation falls largely as rain and contributions from snow and fog are very small. Rainfall is fairly evenly distributed throughout the year with a slight winter maximum (Table 1a). Con-

tributions from snow and fog are very small at this altitude. However, soil moisture is depleted to low values in summer when high temperatures and dry northerly winds increase evapotranspiration. Variability of precipitation is also greater in the summer but this does not exceed world variability for this mean (world figures from Leeper, 1960).

In the study area itself throughfall was measured beneath the forest and found approximately equal to the rainfall in the open at Kinglake for the same period (1962-3). Throughfall was sampled by three roving rain gauges in each of three half-acre plots set up at the ends and centre of the half mile length of the study area. No significant differences were recorded between plots during the two years of collection.

Temperatures are not extreme and the annual mean is probably 54-55°F, 4 or 5 degrees F. cooler than Melbourne. The average maximum, minimum and mean monthly figures for Melbourne are given in Table 1b. Frosts may occur in the study area during winter and spring but damage to plants in the plateau is usually restricted to potato crops and bracken in cleared areas.

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TABLE 1  
METEOROLOGICAL DATA

(a) Mean monthly rainfall in inches for Kinglake (Pheasant Creek), 7 miles east of the study area on the Divide (42 year period)

J	F	M	A	M	J	J	A	S	O	N	D	Total
3.13	2.86	3.52	4.21	4.00	4.82	4.26	4.54	4.19	4.65	3.82	3.94	47.94

(b) Temperature data for Melbourne

	J	F	M	A	M	J	J	A	S	O	N	D
Av. max.	77.7	78.6	74.9	67.9	62.0	56.8	56.2	58.7	63.3	67.9	71.3	75.4
Av. min.	56.9	58.0	55.2	50.8	46.9	43.8	42.6	43.7	46.0	48.7	51.8	55.3
Av. mean	67.3	68.3	65.1	59.3	54.5	50.3	49.4	51.2	54.7	58.3	61.5	65.3

TABLE 2  
PARTICLE SIZE ANALYSIS

Red Soil					Grey Soil				
Depth Inches	% Fine Sand	% Silt	% Clay	*Texture	Depth Inches	% Fine Sand	% Silt	% Clay	*Texture
0-3	42	37	21	S.L	0-3	39	36	25	S.L
3-6	43	34	21	S.L	3-6	39	38	20	S.L
6-12	40	29	31	SCL	6-12	37	33	28	SCL
12-24	30	22	48	SC	12-24	33	34	32	SCL
24-36	30	20	53	C	24-36	31	31	35	SCL
36-48	26	18	59	C	36-48	29	48	26	SCL
48-60	26	20	56	C	48-60	32	49	23	SL
60-66	30	21	53	SC					
66-72	33	24	46	SC	60-72	21	42	41	SC

\* S = Silt, C = Clay, L = Loam

The parent material of the soils in the study area is composed of weathered siltstones and mudstones. It has given rise to two kinds of gradational soil profiles usually about 6 ft deep. Both are acid, have high organic contents in the top 3 in. and a textural variation from silty loam to clay. (See Tables 2, 3 and 4).

One soil has a predominantly red profile (moist surface soil is 2.5 YR 3/6 by Munsell Colour Charts), is well structured and may be classed as a krasnozem or by the synonyms latosol or red loam. The other soil varies from dark grey (10 YR 4/1) in the surface to yellow-brown (10 YR 5/4) in the subsoil, and is not readily classified according to the Great Soil Group System. Northcote (1962) maps this soil as a yellow leached earth (Gn. 3.74) and the former as a red porous friable earth (Gn 4.14). Due to the complication of the nomenclature and classification, the soils here will be referred to as 'grey' and 'red' soils.

TABLE 3

pH\* (means for two profiles 1: 5 suspension)

Depth in inches	Red Soil	Grey Soil
0-3	5.3	4.3
3-6	5.4	4.8
6-12	5.4	5.0
12-24	5.4	5.1
24-36	5.6	5.1
36-48	5.7	5.3
48-60	5.7	5.3
60-72	5.8	5.4

These soils occur as a mosaic over much of the plateau, and with either sharp or diffuse boundaries. No strong correlations between soil type and environment are immediately apparent. On the steep southern slopes of the Divide only grey soils occur and these change from gradational to duplex between the higher slopes and the foothills. On flat, intermittently waterlogged depressions on the plateau, grey gradational soils are usually found; but elsewhere on the plateau red, grey and transitional soils occur on every shade of topographic variation (Fig. 1).

The properties of these soils are similar except for their colour and iron content. Iron occurs largely as haematite in the red soil and as goethite in the grey. Other minerals in the clay fraction of both soils are similar, e.g. kaolinite, chlorite, muscovite and ilmenite (Table 5). Total phosphorus is similar in the surface soils but a rapid depletion with depth occurs in the grey soil (Table 6). In general the soils are low in

TABLE 4

Percentage organic matter (Walkley & Black titration) from two profiles

Depth	Red Soil	Grey Soil
0-3"	12.7 (14.9)*	17.6 (11.9)*
3-6"	7.1	7.2
6-12"	7.7	4.3
12-24"	3.8	2.1

\* The figures in brackets refer to the means of nine additional samples collected over this depth.

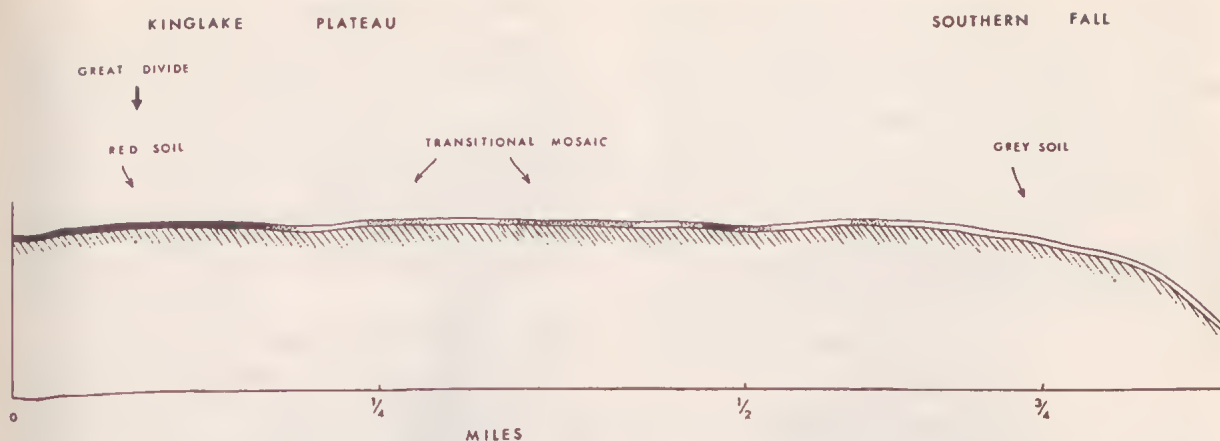


FIG. 1—Soil type distribution on the Kinglake Plateau from a North South transect line  $2\frac{1}{2}$  miles W. of Kinglake West. (Vertical scale = horizontal scale.)

nutrients and extremely high rates of fertilizer application at Kinglake are necessary for successful potato production (Downie, 1961). In agriculture the red soils are perhaps preferred because of their greater permeability.

TABLE 5

Clay mineralogy of Red and Grey Soils from Kinglake West (kindly determined by Dr. G. P. Briner)

Depth	Red Soil	Grey Soil
3-6"	Kaolinite Chlorite Muscovite (trace) Haematite	Kaolinite Chlorite Muscovite Goethite Quartz
60-66"	Kaolinite Ilmenite Haematite Chlorite (trace)	Kaolinite Ilmenite (trace) Goethite Muscovite

TABLE 6

Total Phosphorus in HF extract and total Iron content (kindly analysed by N. C. Uren)

Depth in in.	P (ppm in soil)		Fe%	
	Red	Grey	Red	Grey
0-3	222	200	3.9	1.3
6-12	198	128	4.3	1.9
12-24	170	120	4.6	2.4
36-48	162	115	5.0	4.3
60-72	203	93	4.4	4.1

In order to obtain an indication of the relative fertility of the two soils, seven native species from the study area were grown in pots of sieved topsoil. After five months (September to February) in the glass house the heights and dry weights of the legumes *Pultenaea muelleri*, *P. gunnii* and *Acacia verticillata* were statistically greater in the red than in the grey-soil treatment. *Leptospermum juniperinum*, a species common on soils of impeded drainage and found only on the grey soil of the study area, also grew taller on the red

soil but showed no statistically significant difference in dry weight. *E. radiata* and *E. cypellocarpa* showed no treatment difference in height or dry weight, but in *E. obliqua* both of these attributes were greater on the grey soil.

Physically the soils are both very well structured with stable crumbs in the top soils and nutty sub-angular aggregates at depth. The bulk density of the red soils is lower than that of the grey soils in the surface horizons and moreover increases less steeply with depth (Fig. 2). This suggests that the red soils are better drained than the grey soils. Soil moisture at depths of 0-3" and 12-18", determined gravimetrically at 2-4 weekly intervals during the spring and summer of 1963 and 1964 indicated that the red soils tended to have greater amounts of available water than the grey to a depth of 18 in., and also greater moisture content at the wilting point, due to the somewhat higher clay content.

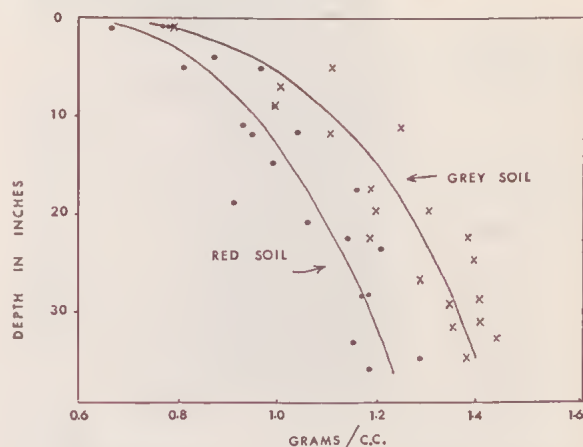


FIG. 2—Bulk density of the red and grey soils in relation to depth.



FIG. 3—Quantitative differences in floristics between soils in the study area.



The vegetation is probably under relatively low grazing pressure from the larger herbivores (wallabies, wombats, possums and rabbits). Fenced and control plots were set up in the forest in 1963. By late 1965, little difference was apparent except for increased quantities of *Poa australis*, *Tetrarrhena juncea* and *Haloragis tetragyna* in the fenced plots. By late 1967 the growth of all plants was greater in the fenced plots, and on both soils *Tetrarrhena juncea* was by far the most conspicuous species.

Fires have occurred in the general area in 1851, 1898, 1905, 1908, 1926 and 1938. Where fires have been severe even aged areas of *E. obliqua*, *E. radiata* and *E. cybellocarpa* have resulted. In many areas older generations of trees which have survived the fires are associated with a variable development of eucalypt regeneration. The undergrowth varies considerably and may be dominated by shrubs and scrambling grass or tussock grasses. The predominance of shrub species which bear fire resistant hard seeds is noticeable (*Acacia*, *Pultenaea* spp.).

## FLORISTICS OF THE COMMUNITY

The floristics of the area was studied by recording the species present in circular plots of 20 ft radius. The plots were spaced at one chain intervals along two parallel lines one chain apart. The lines extended from the Cascades water channel for a distance of 20 chains along the edge of the plateau. Percentage cover of species was subjectively assessed in 5-10% classes (Table 7) and repeatedly checked objectively by vertical point quadrat techniques. (Twenty ft radius plots were used because the minimal area—i.e. that which contains 80% of the species, has a radius of 16 ft). The results showed that, whilst the species composition on both soils was similar, marked

composition is shown in Table 8, and the quantitative relationships are given in Fig. 3. The differences between the cover frequency of the vegetation components on the two soils can be better expressed if the frequency of occurrence of species above certain cover classes are considered. Thus the overall frequency of occurrence of *Pultenaea muelleri* is the same on both soils, but the frequency of it with cover values >5% is markedly greater on the red soil. Similarly, the preponderance of *Tetrarrhena juncea* on the red soil areas is greater if the cover classes from 25% to 50% are considered.

TABLE 8

Species found to be more frequent on one soil compared to the other

On Red Soil	On Grey Soil
<i>Clematis aristata</i>	<i>Leptospermum juniperinum</i>
<i>Poa australis</i> (coarse var.)	<i>Lindsaya linearis</i>
<i>Geranium pilosum</i>	<i>Drosera auriculata</i>
<i>Hydrocotyle lirta</i>	<i>Dianella tasmanica</i>
<i>Tetratheca ciliata</i>	<i>Hypochoeris radicata</i>
<i>Pultenaea scabra</i>	<i>Lomandra</i> spp.
<i>Spyridium parvifolium</i>	<i>Poranthra microphylla</i>
<i>Acacia verticillata</i>	<i>Epacris impressa</i>
<i>Asterolasia asteriscophora</i>	<i>Pultenaea gunnii</i>
<i>Eucalyptus cybellocarpa</i>	<i>Acacia mucronata</i>
<i>Pimelia axiflora</i>	<i>Correa reflexa</i>
	<i>Acacia falciformis</i>
	<i>Cyathea australis</i>

It is suggested that the greater growth of the understorey on the red soil is due to the slightly faster rate of pyric succession.

Differences in the occurrence of macrofungi also occur on the two soil types: a large number is common to both and relatively few are found only on one soil. A list of species is given in Appendices 1 and 2.

## STRUCTURE OF THE COMMUNITY

### (a) OVERSTOREY

The forest structure on the red and grey soils was studied by means of accurate profiles and plans in typical areas of almost flat terrain at both ends of the main transects (Fig. 4, 5, 6, 7). The canopy of the forest is fairly uneven with the major part of it between 80-120 ft. Crown depth makes up about  $\frac{1}{2}$ – $\frac{1}{3}$  of the total height. Degenerate trees occur here and there with emergent stag-headed crowns and fluted butts bearing old fire scars. The girths of these trees at breast height reach 19'9" for *E. obliqua* and 11'9" for *E. radiata*. The corresponding maximum heights of these species are 140 ft and 120 ft, although some of the large-girthed trees may be broken off at heights of 20-80 ft. The main components of this stratum are mature and half grown trees of spar and pole size, with flat-topped to sub-conical

TABLE 7

Cover classes used in assessments of Species

Per cent Cover	Cover Class
0-5	+
6-10	1
11-20	2
21-30	3
31-40	4
41-50	5
51-60	6
61-70	7
71-80	8
81-90	9
91-100	10

differences in the cover and frequency of species were evident. The major tree species on both soils were *E. obliqua* and *E. radiata*. In the study area *E. cybellocarpa* occurs chiefly on the red soil. The major qualitative differences in floristic



FIG. 4—Profile diagram of forest on the red soil area.

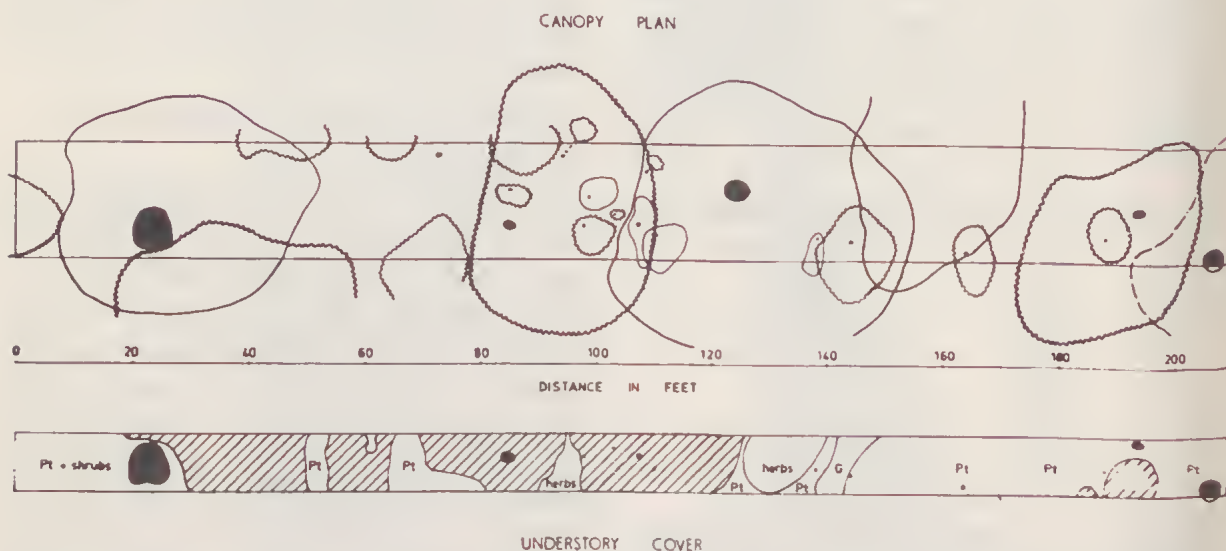
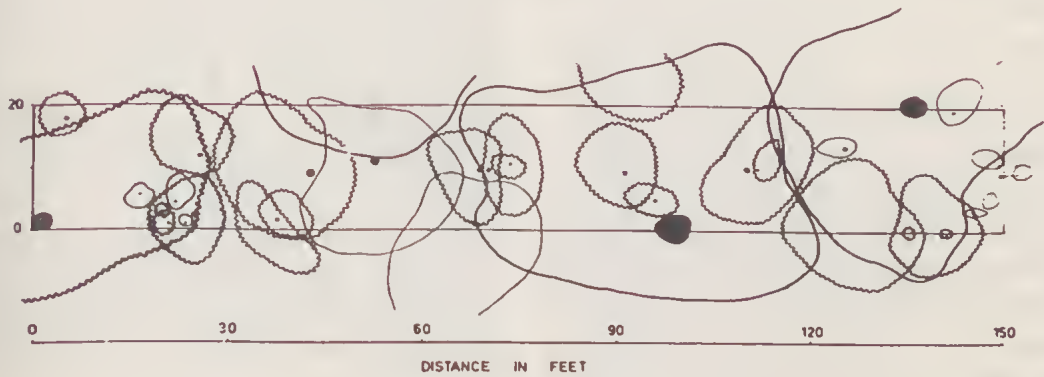


FIG. 5—Plan of forest section depicted in Fig. 4. Trees with foliage unshaded are *E. obliqua*. Trees with foliage stippled are *E. radiata*. Tree with broken outline is *E. cytellocarpa*. Hatched shading on shrub layer = *Pultenaea muelleri*.  
 G = *Goodenia ovata*  
 Pt is *Pteridium esculentum*



FIG. 6—Profile diagram of forest on grey soil area.

## CANOPY PLAN



## UNDERSTORY COVER

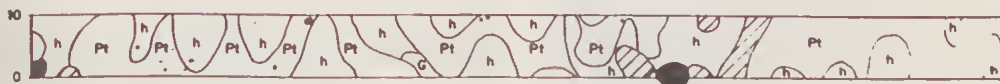


FIG. 7—Plan of forest section depicted in Fig. 6. Trees with foliage stippled are *E. radiata*. Trees with foliage unshaded are *E. obliqua*. Hatched shading on shrub layer = *Pultenaea muelleri*.  
 Pt = *Pteridium esculentum*                      G = *Goodenia ovata*  
 R = small *E. radiata* plants                      h = herbs



TABLE 9  
Analysis of Pattern of Smaller Eucalypt Stems

Block size sq. ft	Number of blocks	Mean density m	Density variance V	V/m	Standard error of V/m	't'	Significance	
							(Greig Smith)	(Thompson)
100	324	0.228	0.294	1.29	0.0787	3.672	P<0.001	P<0.05
400	81	0.91	1.46	1.60	0.111	5.405	P<0.001	P<0.05
900	36	2.06	3.71	1.80	0.167	4.790	P<0.001	P<0.05
3600	9	8.22	13.25	1.61	0.333	1.832	N.S.	N.S.
8100	4	18.5	25.7	1.39	0.500	<1	N.S.	N.S.

crowns. It is likely that trees of several ages occur in this stratum and that each generation has arisen following severe fires. The large-girthed trees probably exceed 100 years. Large pole-size trees 70-80 ft high bear about 40-50 rings and result from the 1926 fires.

The plan and profiles show that while overlapping of the crowns may occur, interlacing of them is absent or rare. This 'crown shyness' has been attributed by Jacobs (1955) to the sensitivity of the naked buds. In general the overall stature of the forest is somewhat greater on the red soil than the grey.

A second stratum of eucalypts is composed of trees 20-50 ft high. These trees have shallow open crowns and are oppressed or suppressed beneath the canopy of the larger trees. The patterns of distribution of the size classes of the three eucalypt species were studied on an area 120 × 270 ft in the forest on the red soil. The plot was divided into 10 × 10 ft squares and each tree or seedling growing thereon was charted. The plot data were combined in regular multiples according to the method of pattern analysis of Greig-Smith (1964). The deviation of the variance: mean ratio from unity was tested by methods of Kershaw (1964) and Thompson (1958). In both cases statistically significant aggregation of eucalypts <24 inches g.b.h. and 55 ft height, occurred in all plot sizes up to 900 square ft in area (Table 9). Beyond this size their distribution was at random. Although clumping of such plants cannot be correlated in any simple way with present gaps in the canopy, a relationship may have been evident at the time of their establishment following the bushfires of 1926. The taller and larger trees in the plot were found to be randomly distributed at all plot sizes. These trees comprise both the older age classes and the dominant individuals of the 1926 regeneration.

Throughout the area an inconspicuous stratum of eucalypts up to 5-6 ft in height may be found amongst the shrubs and bracken (*Pteridium escu-*

*lentum*). These eucalypts usually bear few leaves and often show stem dieback. Many of these plants show evidence of having had several generations of shoots from the lignotubers at or below the soil surface and it is suggested that such plants arose following the 1926 bushfires and have persisted in an extreme state of suppression (Table 10). However, some small plants have been found without evidence of several shoot generations and with only 6 and 16 rings in two particular cases. Other similar plants have been found on recently-upthrown root-mounds and on rotten logs, indicating that a certain proportion of this class has arisen without the intervention of fire.

The relative species composition of the forest canopy varies with site quality and height in the stand. In general *E. obliqua* is more common than *E. radiata* in the upper parts of the forest canopy and moreover tends to be more common on the red soil than on the grey. In the second stratum (20-50 ft) *E. radiata* is much more common than *E. obliqua* on both soils. *E. cypello-carpa* is absent on the grey soils (except along drainage lines) and its presence on the red soils is sporadic in the larger classes, although somewhat more frequent in the very small suppressed classes.

Although observations of both even-aged and mixed-aged forests suggest that *E. radiata* is relatively more common than *E. obliqua* among the lower height classes than in the taller classes, a more quantitative assessment of the phenomenon was desired.

TABLE 10  
Ring counts on *Eucalyptus* from the 20-35 ft sub-stratum of the Forest

Species	G.B.H. in ins.	Ring count at base	Years since fire	Year of count
<i>E. radiata</i>	10	33	37	1963
"	10	38	37	1963
"	6	24	37	1963
"	5	35	37	1963
"	12	38	40	1966

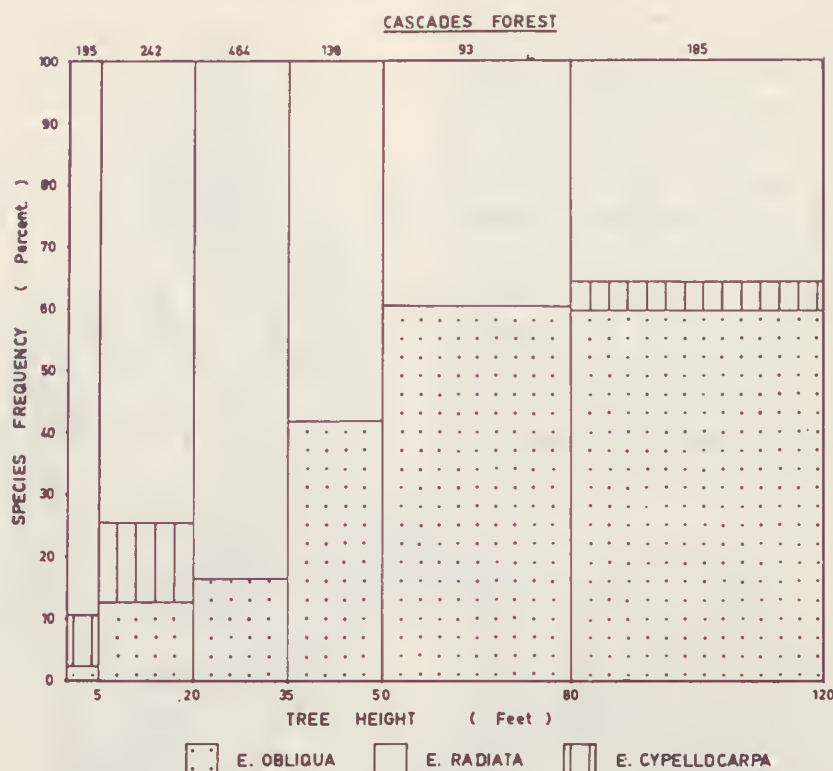


FIG. 8—Change in eucalypt-species proportions according to tree height.

The large number of girth measurements taken by plot sampling was converted to height data by regression analysis and the regression data were processed by first separating the 'sub-canopy' trees (< 80 feet tall) from the 'canopy' trees (> 80 feet tall). For the sub-canopy trees the regression coefficients for height on girth breast height were very high and statistically significant—i.e. 0.990 for *E. obliqua* and 0.975 for *E. radiata*. For the canopy trees the variability of height was great (due to stag-headed trees for example) but the average height varied little with a large change in girth. The overall average height for the canopy trees on the red soil was higher than for those on the grey. For purposes of comparison of species proportions within various strata of the forest the canopy trees have been considered as one broad class embracing both soils. Comparisons among sub-canopy trees are also based on combined data, as the regressions for the two species on the two soils were very similar. The comparison between species frequencies in broad height groups within the forest are shown in Fig. 9.

A further check on the change in species relationships within the forest was made by the collection of direct height data for the two species

on each soil. The same relation as that predicted by observation and conversion of girth data to height data by regression, was revealed by this direct method also: the proportion of *E. radiata* plants in the lower strata of the forest is much greater than in the upper.

#### (b) THE UNDERSTOREY

The understorey consists of an interrupted and patchy shrub stratum of various legumes (*Acacia verticillata*, *A. falciformis*, *Pultenaea muelleri*, *P. scabra*, *P. gunnii*) 5-20 ft high, an open lower stratum of rhizomic ferns (*Pteridium*, *Culcita*), grasses (*Tetrarrhena*, *Poa*), low shrubs and herbs. The dominant shrub *Pultenaea muelleri* occurs in dense patches and thickets and is conspicuously

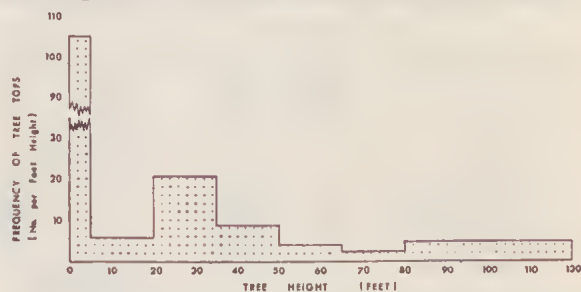


FIG. 9—Histogram of heights of eucalypts from both soil types.

taller and denser and better developed on the red soil areas than on the grey soil areas under similar canopy densities of *E. obliqua* and *E. radiata*. The patches of *P. muelleri* are frequently domed or conical in profile but may show dieback and death in the centre with the formation of hollow rings 15-20 ft in diameter. Excavations of the root systems show that the clumps expand vegetatively, although the possibility of seedling regeneration cannot be ignored. Sections of the horizontal connections between stems showed that these structures were roots and that the vegetative spread occurred by means of root suckers (Fig. 10). Ring counts at the stem bases were usually clear and showed a high correlation coefficient (0.979) with height. Such relationships were found to hold only within individual clumps: the tallest plants measured were 16 ft high and appear to be about 15 years old.

On the basis of size and vigour, clumps of *P. muelleri* can be arbitrarily classified into five stages (Table 11) depicting its advance and ultimate degeneration and death. One clump with a hollow centre was studied in detail and plan and profile diagrams were made (Fig. 11, 12). The results of this study indicate that the older stages form an annulus and that the centre is now being recolonized by young sucker plants. Many mature clumps died during the 1967 drought.

In spite of the density of the *Pultenaea* stems there appears to be relatively little correlation with the occurrence of developmental stages and the presence of other species. The main correlation that can be seen is the greater abundance of bracken (*Pteridium esculentum*) in the pioneer stages of *Pultenaea* and its scarcity in the mature phases of the shrub. Most patches have not developed the hollow centre, but this may be merely a reflection of the age of its development following the last disturbance by fire. A well developed patchy stratum of *P. muelleri* is likely to be the expression of mature understorey in this association since a repetition of it can be found in many other similar stands on the Hume Range. The pattern of stem densities of this shrub

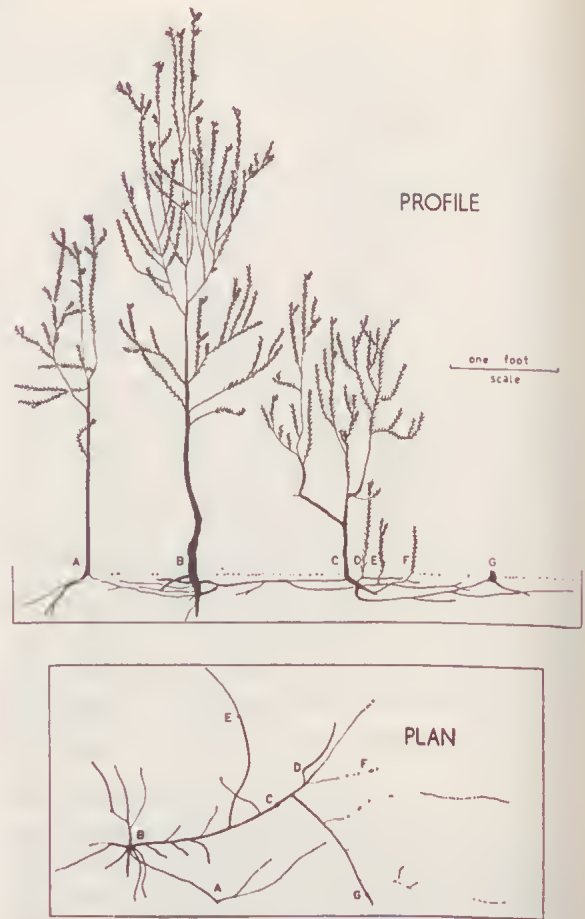


FIG. 10—Profile showing root connections between shoots.

suggest that it follows a cyclic development of continual change in time and space similar to that of other species described by Watt (1947).

(c) DISCUSSION

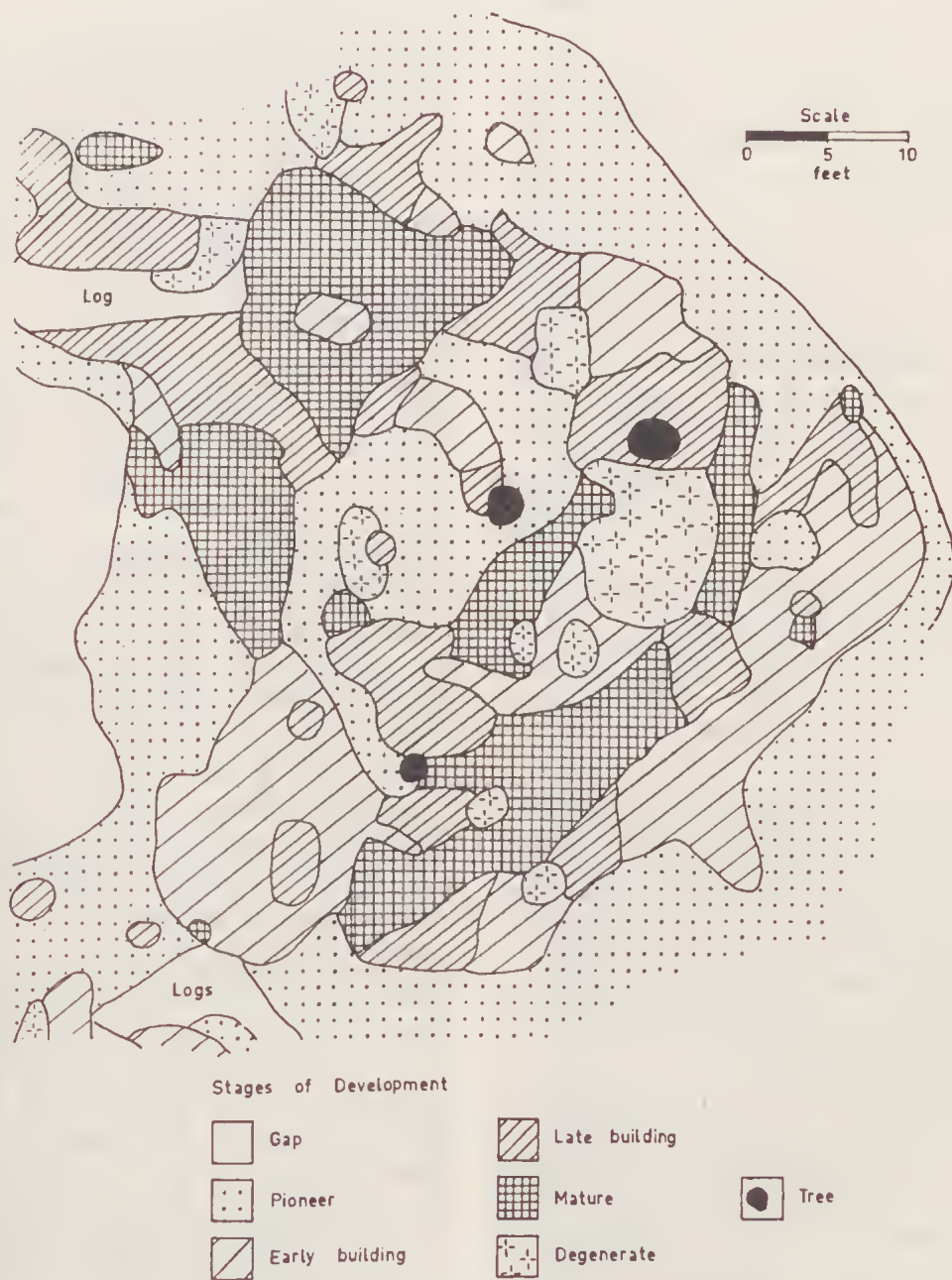
A number of lines of evidence suggest that the red soil area has slightly higher site quality than the grey soil area. The evidence comes from the pot experiments (where growth of native legumes was greater in the red soil in the glasshouse), from agriculture (where the red soils are favoured for potato growing), from the heights of the same aged forests on the two soils (tend to be greater on the red soil), and from the development of the understorey (*Pultenaea muelleri* shows greater development on the red soil and is a major component of the understorey). However these differences are not extreme and the different species-frequencies on the two soils in the study area may be explained by slightly greater rate of succession after fire on the red soils.

TABLE 11  
Classification of *P. muelleri* for plan diagram of a single clump

Stage	Height (ft)	Vigour
1. Pioneer	0-2	Good
2. Early building	2-3½	"
3. Late building	3½-5½	"
4. Mature	>5½	"
5. Degenerate	>5	Dying out in numbers*

\* This was especially so in the dry summers 1965-8.



PLAN OF A *PULTENAEA MUELLERI* CLUMPFIG. 11—Plan of a *Pultenaea muelleri* clump on red soil.

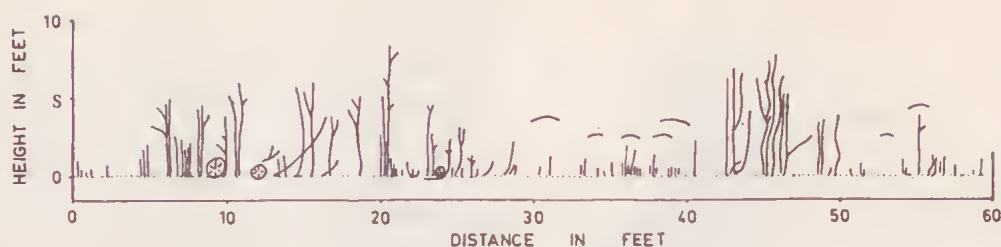


FIG. 12—Profile across widest diameter of clump in Fig. 11.

The main canopy of the forest appears to be of mixed age, as the forms and sizes of the trees are so varied in comparison to stands known to be even-aged. The even-aged forests of the area are composed of the same species as this study and arose following severe fires in the past. Ring counts on trees 20-70 ft high in the mixed-age forest in this study area suggest they arose following the last fire. The variation in ring counts is probably due to the omission of rings under suppressing conditions as has been noted by Bormann (1965), and the duplication of rings following an interruption of the growing period by drought. It is unlikely that any of these plants have arisen in the interfire period, although some of the very small stunted plants of the shortest stratum may have done so, as in the regeneration of the jarrah (*E. marginata*) forests of Western Australia (van Noort, 1960).

The reasons for the change in *E. radiata* proportion with height in the forest do not appear to be related to different susceptibilities of the two dominant eucalypt species to sub-canopy light intensities *per se* (Gill, 1966), but rather to the combination of this factor with other microclimatic and edaphic factors. Attitwill (1964) has shown that in spar stage forest of *E. obliqua* on red soil on Mt. Disappointment the deficiency of available phosphorus may be an important factor limiting the growth of eucalypt regeneration. Patterns of eucalypt stem distribution are closely related to catastrophic fires at irregular intervals. Thus the clumps of small eucalypt stems in this study may be related both to death of large stems and regeneration in gaps after fire. Canopy closure after fire may obscure any early relation between gaps and regeneration.

It is possible that the increased development of *Pultenaea muelleri* thickets, bracken and wiregrass (*Tetrarrhena*) with maturity of overstorey could result in more restricted opportunities for seedling regeneration of eucalypts. It seems likely that the greater persistence of *E. radiata* seedlings and saplings and the limited success of this species in establishment in this forest without fire could result in a greater preponderance of it in

the future. It is suggested (Jacobs 1955, p. 124) that if the oppressed plants of *E. radiata* continue to persist and maintain their ability to recover from suppression, the long-term absence of fire may gradually convert the stand to *E. radiata* dominance. With the intervention of crown and ground fires the original predominance of *E. obliqua* could be restored.

### CLASSIFICATION OF THE COMMUNITY

A physiognomic classification is the most accepted in Australia (Beadle & Costin, 1952; Webb, 1959; Wood & Williams, 1960; Leeper 1970). The major criteria used in such a classification are plant form, size and abundance, stratification, leaf size and texture and the presence or absence of epiphytes.

Maturity has been suggested as a prerequisite to classification (Beadle & Costin, 1952; Wood & Williams, 1960), but such a criterion may result in the interpretation of communities rather than their classification. Plant communities at all stages of maturity should be described and classified objectively and then interpreted.

The community of the present study is composed largely of trees of forest form with an understorey of short (1 to 6 ft) to tall (6 to 25 ft) shrubs with small (nanophyll) leaves.

In the study area the mixed-aged forest contains many mature and degenerate trees and small groups and patches of 40 year old pole stage trees. The last major fire in the area was that which permitted the regeneration of the pole-stage class. The study of the understoreys of the study area suggest that the *Pultenaea muelleri* - *Pteridium esculentum* - *Tetrarrhena jaunceae* type is a self-perpetuating stratum throughout much of this forest on both soil types. Dense even-aged pole-stage forests generally have an understorey of *Pteridium esculentum* with a meagre development of *Pultenaea muelleri* and other shrubs. It is likely that changes in the understorey will accompany changes in the density and form of the overstorey. In some red soil sites in the study area the establishment of scattered

broad-leaved (notophyll) shrubs, such as *Pomaderris aspera*, *Olearia argophylla* and *Bedfordia salicina* has occurred. The sporadic occurrence of *Cyathea australis* in this forest is correlated with special niches such as the depressions formed by the upthrown roots of fallen trees. It is possible that with further maturation of the overstorey and a continued absence of fire, further establishment of the broad-leaved shrubs may occur. In such an eventuality this tall open-forest formation would need to be reclassified from a dry sclerophyll to a wet sclerophyll sub-form. It seems therefore that the classification of the forests of the Kinglake West area may depend on the frequency and severity of burning and the maturation of the overstorey and understorey.

## ACKNOWLEDGMENTS

We would like to thank Professor J. S. Turner for the use of the facilities of the Botany Department, University of Melbourne, and the Melbourne and Metropolitan Board of Works for permission to work in the area. One of us (A.M.G.) is indebted to the University of Melbourne and the Australian Cattle and Beef Research Committee for scholarships during the course of this work.

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## APPENDIX 1:

## VASCULAR PLANTS OF THE STUDY AREA

### PTERIDOPHYTA

#### CYATHACEAE

*Cyathea australis* (R. Br.) Domin.

#### DENNSTAEDTIACEAE

*Culcita dubia* (R. Br.) Maxon.

*Histiopteris incisa* (Thunb.) J. Smith.

*Pteridium esculentum* (Forst.f.) Nakai.

#### LINDSAYACEAE

*Lindsaya linearis* Swartz.

#### BLECHNACEAE

*Blechnum nudum* (Labill.) Mett.

### ANGIOSPERMAE

#### MONOCOTYLEDONAE

#### GRAMINAE

*Danthonia penicillata* (Labill.) Pal. Beav.

*Deyeuxia quadriseta* (Labill.) Benth.

*D. rodwayi* J. W. Vickery.

*Microlaena stipoides* (Labill.) R. Br.

*Poa australis* spp. agg.

*Tetrarrhena juncea* R. Br.

#### CYPERACEAE

*Galinia sieberiana* Kunth.

*Lepidosperma elatius* Labill.

#### LILIACEAE

*Dianella tasmanica* Hook.f.

*Burchardia umbellata* R. Br.

*Lomandra longifolia* Labill.

*L. filiformis* (Thunb.) Britten.

*Thysanotus tuberosus* R. Br.

#### ORCHIDACEAE

*Caladenia* spp.

*Chiloglottis gunnii* Lindl.

*Prasaphyllum brevifolium* (Lindl.) Hook.f.

*Pterostylis longifolia* R. Br.

*Thelymitra media* R. Br.

*Cryptostylis leptochila* F. Muell. ex. Benth.

#### DICOTYLEDONAE

#### PROTEACEAE

*Lomatia ilicifolia* R. Br.

#### RANUNCULACEAE

*Ranunculus hirtus* Bks. and Sol.

*Clematis aristata* R. Br. ex DC.

#### DROSERACEAE

*Drosera auriculata* Baekh. ex Planch.

#### PITTOSPORACEAE

*Billardiera scandens* Sm.

#### ROSACEAE

*Acaena anserinifolia* (Forst. & Forst.f.) Druce.



## LEGUMINOSAE

*Acacia falciformis* DC. now *A. obliquinervia* Tindale.

*A. melanoxylon* R. Br.

*A. mucronata* Willd. ex H. Wendl.

*A. verticillata* (L'Hérit.) Willd.

*Daviesia ulicifolia* Andr.

*Pultenaea gunnii* Benth.

*P. scabra* R. Br.

*P. muelleri* Benth.

## GERANIACEAE

*Geranium pilosum* Forst.f. ex Willd. now *G. potentilloides* L'Hérit. ex D.C.

## OXALIDACEAE

*Oxalis corniculata* L.

## RUTACEAE

*Asterolasia asteriscophora* (F. Muell.) Druce.

*Correa reflexa* (Labill.) Vent.

## TREMADRACEAE

*Tetratheca ciliata* Lindl.

## POLYGALACEAE

*Comesperma volubile* Labill.

## EUPHORBIACEAE

*Amperea xiphoclada* (Sieb. ex Spreng.) Druce.

*Poranthera microphylla* Brongn.

## STACKHOUSIACEAE

*Stackhousia monogyna* Labill.

## RHAMNACEAE

*Pomaderris aspera* Sieb. ex DC.

*Spyridium parvifolium* (Hook.) F. Muell.

## GUTTIFERAE

*Hypericum japonicum* Thunb.

## VIOLACEAE

*Viola hederacea* Labill.

## THYMELIACEAE

*Pimelea axiflora* F. Muell.

*P. linifolia* Sm.

## MYRTACEAE

*Eucalyptus cypellocarpa* L. Johnson (formerly *E. goniocalyx* F. Muell.)

*E. obliqua* L'Hérit.

*E. radiata* Sieb. ex DC.

*Leptospermum juniperinum* Sm.

## HALORAGACEAE

*Haloragis tetragyna* (Labill.) Hook. f.

## ARALIACEAE

*Astrotricha asperifolia* F. Muell. ex Klatt.

## UMBELLIFERAE

*Hydrocotyle hirta* R. Br.

*Xanthosia dissecta* Hook. f.

## EPACRIDACEAE

*Acrotriche serrulata* R. Br.

*Epacris impressa* Labill.

## GENTIANACEAE

*Centaurium minus* Moench.

## LABIATAE

*Prostanthera hirtula* F. Muell.

## RUBIACEAE

*Asperula scoparia* Hook. f.

*Coprosma quadrifida* (Labill.) Robinson

## CAMPANULACEAE

*Lobelia gibbosa* Labill.

*Wahlenbergia gracilis* A.DC.

## GOODENIACEAE

*Goodenia elongata* Labill.

*G. ovata* Sm.

## STYLIDIACEAE

*Stylidium graminifolium* Swartz

## COMPOSITAE

*Bedfordia salicina* (Labill.) DC.

*Cassinia aculeata* (Labill.) R. Br.

*Gnaphalium japonicum* Thunb.

*Hypochoeris radicata* L.

*Lagenophora stipitata* (Labill.) Druce

*Leontodon taraxacoides* (Vill.) Merat.

*Olearia argophylla* (Labill.) Benth.

*O. philogopappa* (Lab.) DC.

*O. lirata* (Sims.) Hutch.

*O. erubescens* (Sieb. ex DC.) Dippel.

*O. rugosa* (F. Muell. ex Arch.) Hutch.

## APPENDIX 2:

## MACROFUNGI RECORDED FOR THE STUDY AREA FOREST ON THE RED AND GREY SOILS DURING 1962-1964

(\*Some species recorded only for grey soil which occur on red soil in *E. regnans* forest.)

	Red Soil	Grey Soil
<i>Aleuria aurantia</i>	+	
<i>Boletus multicolor</i>	+	
<i>B. brunneus</i>	+	
<i>Cortinarius austrovenetus</i>	+	
<i>C. albidus</i>	+	
<i>C. lavendula</i>	+	
<i>Clavaria botrytis</i>	+	
<i>Calostoma fusca</i>	+	
<i>Collybia percava</i>	+	
<i>Galera crispa</i>	+	
<i>Hebeloma mesophaeum</i>	+	
<i>Inocybe granulospes</i>	+	
<i>Pleurotus lampas</i>	+	
<i>Russula erumpens</i>	+	
<i>R. delicata</i>	+	
<i>Polyporus sacer</i>	+	
<i>Cortinarius archeri</i>	+	+
<i>C. custanofulvus</i>	+	+
<i>Clavaria sinapicolor</i>	+	+
<i>C. ochraceosalmonicolor</i>	+	+
<i>Hypholoma fasciculare</i>	+	+
<i>Hydnum graveolens</i>	+	+
<i>H. repandum</i>	+	+
<i>Laccaria laccata</i>	+	+
<i>Lactarius seriffusus</i>	+	+
<i>Lepiota suberitata</i>	+	+
<i>Mesophellia arenaria</i>	+	+
<i>Pleurotus viscidulus</i>	+	+
<i>Paxillus infundibuliformis</i>	+	+
<i>Russula purpureoflava</i>	+	+
<i>Tricholoma coarctata</i>	+	+
<i>T. terreum</i>	+	+
<i>Ananita grisea</i> *		+
<i>A. ochrophylla</i>		+
<i>Boletus erythropus</i>		+
<i>Cortinarius cinnamomeus</i> *		+
<i>C. subarcheri</i>		+
<i>C. microarcheri</i>		+
<i>C. cinnabarinus</i> *		+
<i>C. sublargus</i>		+
<i>Clavaria australiana</i> *		+
<i>Collybia radicata</i> *		+
<i>Hysterangium neglectum</i>		+
<i>Lepiota cristata</i> *		+
<i>Russula xerampina</i>		+
<i>R. pectinoides</i> *		+
<i>Rozites australiensis</i>		+

Note: Species were determined largely from Cleland, *Fungi of South Australia*.

## TERTIARY CHEILOSTOMATOUS BRYOZOA FROM VICTORIA

## A Revised Stratigraphical Distribution

By A. E. COCKBAIN\*

**ABSTRACT:** Recent work on the geology of Southwest Victoria (Kenley and others, 1964, 1967) shows that the cheilostomatous bryozoans described by Brown (1958) came from beds now assigned to Carter's (1964) faunal units 4 and 5 (Janjukian) and 6 and 7 (Longfordian). A revised stratigraphical distribution table for Brown's species is presented and the new names Koonalunda Lens and Wilkin Beds applied to two members of the Gambier Limestone.

## INTRODUCTION

Cheilostomatous Bryozoa have been described from Tertiary rocks in Victoria by several workers in the past hundred years. Most of this work has been systematic and few attempts have been made to summarize the stratigraphical distribution of cheilostomes. Etheridge's (1878) 'Synopsis' and Maplestone's (1904) more complete 'Tabulated List' both lack adequate stratigraphical control. Crespin's (1943) faunal distribution tables, whilst more exhaustive, give the fossil ranges in terms of stages rather than formations; since many of these stages now have different limits it is not easy to update these tables.

In 1958, Brown published a systematic account of the fossil cheilostomatous Bryozoa from southwest Victoria and tried to use the faunas to date the rocks. He recognized five faunas—Glenaulin Fauna, Watapoolan Fauna, Sandford Limestone Fauna, Sample 18 Fauna and Myaring Fauna. On the basis of a quantitative comparison, he stated (Brown, 1958, p. 29): '... it appears that the Myaring faunas fall into a category distinct from that of the remaining four groups considered and, in my opinion, the polyzoan faunas of these latter are very closely related and indicate a relatively small age difference between them'.

Brown's stratigraphical conclusions were summarized as follows (p. 7): 'The faunules of the Glenaulin Clay and Watapoolan Limestone are closely related and probably are slightly older than the Sandford Limestone of Janjukian age. The faunules of the Myaring Beds appear to be

younger and are probably of Balcombian Age'. Brown gave detailed lists of the bryozoans occurring in each sample and formation, and hence it is possible to revise the stratigraphical ranges of his species following recent increases in our knowledge of the geology of southwest Victoria. This paper presents such revised ranges and amply substantiates Brown's opinion (p. 7) . . . 'There is good evidence that the Polyzoa are of considerable value for stratigraphical correlation'.

## STRATIGRAPHY

Recent geological mapping (Kenley and others, 1964, 1967) and palaeontological examination (Taylor, 1964) of the Tertiary rocks in southwest Victoria by the Geological Survey of Victoria have resulted in certain changes in the stratigraphical interpretation of the strata from which Brown's samples were obtained and have provided independent datings and correlations of the formations by means of foraminifers. The samples numbers and formations given by Brown (1958) are summarized in Table 1 and the currently adopted stratigraphic framework is given

TABLE 1

Rock Units	Sample Numbers
Glenaulin Clay	1, 2, 16, 17, 25
Watapoolan Limestone	(3), 4, ?15, ?18, 26, (27)
Sandford Limestone	5, 6, 22, 23, 24
Myaring Beds	7, 8, 9, 10, 11, 12, 13, 14, ?19, ?20, ?21.

*Sample numbers in brackets represent samples which yielded no bryozoans. (Modified from Brown, 1958.)*

\* Geological Survey of Western Australia, Mineral House, Perth, W.A. 6000.

Present Address: c/- Wm. Johnson & Assoc. Pty. Ltd., 196 Adelaide Terrace, Perth, W.A. 6000.

in Table 2. All the stratigraphical units are subdivisions of the Gambier Limestone. The current views are:

1. Brown's Glenaulin Clay samples all came from the Glenaulin Clay Member which foraminifers suggest (Taylor 1964, unpublished) is Faunal Unit 4 in age (all ages are given in terms of the foraminiferal Faunal Units of Carter, 1964).

2. The Wataepoolan Limestone 'marl' samples (3, 4 and 26; see Brown, 1958, Fig. 2, section A) came from a marl lens between the top of the Glenaulin Clay Member and the Wataepoolan Limestone Member and here called the Koonalunda Lens. Foraminiferal evidence suggests that the Koonalunda Lens is low in Faunal Unit 5.

3. The only sample from the Wataepoolan Limestone Member is Sample 27 which contains no identifiable bryozoans. On the basis of foraminifers the Member is Faunal Unit 8 in age.

4. Brown's Myaring Beds samples are now considered to come from two stratigraphical units. Samples 9, 10, 11, 12, 13 and 14 were collected from the Myaring Beds as now restricted, that is the Upper Member of the Gambier Limestone in the Glenelg Valley, and Samples 7, 8, 19, 20 and

21, together with Sample 18 (regarded as ?Wataepoolan Limestone by Brown, 1958) came from the Lower Member of the Gambier Limestone, here named the Wilkin Beds. Foraminifers indicate that the Wilkin Beds are Faunal Unit 5 in age and the Myaring Beds (s.s.) span Faunal Units 6 and 7.

5. The samples from the Sandford Limestone are unchanged, although only two (22 and 23) can be reliably dated and on foraminiferal evidence (Taylor, loc. cit.) are Faunal Unit 6 in age.

6. It is still uncertain from which formation Sample 15 came; Dr. C. Abele, on the basis of foraminifers, considers it to be Faunal Unit 5 (possibly 4) in age.

### REVISED DISTRIBUTION OF CHEILOSTOMATA

With the new stratigraphical information summarized above, it is possible to re-draw Brown's (1958) Distribution Table to show the formations in which the various bryozoans occur and the age range of the species in terms of Carter's Faunal Units. Such a table has been constructed (Table 3) using only those samples that can be con-

TABLE 2

Rock-stratigraphic Unit	Sample	Victorian Tertiary Stage	Carter's (1964) Faunal Unit
Glenaulin Clay Member	25, 16, 17 1, 2.	Janjukian	4
Koonalunda Lens	26, (3), 4.	Janjukian	5
Wilkin Beds - Dartmoor area	21, 18, 19, 20.	Janjukian	5
Myaring area	7, 8.	Janjukian	5
Myaring Beds	9, 10, 11, 12, 14, 13.	Longfordian	6
		Longfordian	7
Sandford Limestone - Red Cap Creek area	22, 23.	Longfordian	6
Sandford area	-	-	-
Wataepoolan Limestone Member	(27)	Longfordian	8

*Note: Sample numbers are listed in ascending stratigraphical order; numbers in brackets represent samples which yielded no bryozoans. Samples 24 (Sandford Limestone, Red Cap Creek area), 5 & 6 (Sandford Limestone, Sandford area) and 15 (uncertain origin) have been omitted from table, since they cannot be reliably dated.*



TABLE 3

## REVISED DISTRIBUTION OF CHEILOSTOMATA FROM SOUTH-WEST VICTORIA

Formations: G = Glenaulin Clay Members; K = Koonalunda Lens; W = Wilkin Beds;  
S = Sandford Limestone Members; M = Myaring Beds  
Faunal Units of Carter 1964: 4 and 5 = Janjukian; 6 and 7 = Longfordian

Nos. #		G	K	W	S	M.	4	5	6	7
24	<u>Odontionella bullata</u> Brown	*					*			
32	<u>Chaperia?</u> sp. nov. Brown	*					*			
33	<u>Onychocella</u> sp.	*					*			
45	<u>Lunulites parvicella</u> (Woods)	*					*			
64	<u>Cellaria grandis</u> Maplestone	*					*			
71	<u>Cellaria stachi</u> Brown	*					*			
78	<u>Menipea biaviculata</u> Maplestone	*					*			
87	<u>Figularia kenleyi</u> Brown	*					*			
103	<u>Gigantopora</u> sp.	*					*			
137	<u>Bulbipora areolata</u> MacGillivray	*					*			
145	<u>Escharoides erecta</u> Canu & Bassler	*					*			
147	<u>Bathosella bulbosa</u> Canu & Bassler	*					*			
160	<u>Smittina cribraria</u> (MacGillivray)	*					*			
166	<u>Smittina</u> sp.	*					*			
187	<u>Adeonellopsis glenaulinensis</u> Brown	*					*			
201	' <u>Cellepora</u> ' sp. 1	*					*			
7	' <u>Membranipora</u> ' <u>longipes</u> Maplestone	*	*				*	*		
10	' <u>Membranipora</u> ' <u>crespiniae</u> Brown	*	*				*	*		
56	<u>Crateropora inconspicua</u> Brown	*	*				*	*		
67	<u>Cellaria dennanti</u> MacGillivray	*	*				*	*		
100	<u>Bimicroporella watersi</u> Brown	*	*				*	*		
106	<u>Arthropoma torquis</u> Brown	*	*				*	*		
121	' <u>Schizoporella</u> ' <u>parvisinuata</u> Brown	*	*				*	*		
130	<u>Hippoporina incomposita</u> Brown	*	*				*	*		
138	<u>Myriapora operculata</u> (Canu & Bassler)	*	*				*	*		
156	<u>Palmicellaria otwayensis</u> (Maplestone)	*	*				*	*		
18	<u>Glenelgia crawfordensis</u> Brown	*	*	*			*	*		
52	<u>Aspidostoma airense</u> Maplestone	*	*	*			*	*		
54	<u>Crateropora patula</u> (Waters)	*	*	*			*	*		
89	<u>Cribrilaria radiata</u> (Moll)	*	*	*			*	*		
101	<u>Gigantopora tuberculosa</u> (Maplestone)	*	*	*			*	*		
146	<u>Escharoides osburni</u> Brown	*	*	*			*	*		
169	<u>Escharella elongata</u> (Canu & Bassler)	*	*	*			*	*		
176	' <u>Retepora</u> ' <u>tridentata</u> Brown	*	*	*			*	*		
68	<u>Cellaria cucullata</u> MacGillivray	*		*			*	*		
2	<u>Biflustra regularis</u> (Maplestone)	*	*	*	*		*	*		
6	' <u>Vincularia</u> ' <u>gigantea</u> Canu & Bassler	*	*	*	*		*	*		
22	<u>Foveolaria thomasi</u> Brown	*	*	*	*		*	*		
155	<u>Palmicellaria quadrifrons</u> Maplestone	*	*	*	*		*	*		
157	<u>Palmicellaria ornata</u> Brown	*	*	*	*		*	*		

# Brown, 1958.

Note: No 201 (line 16). For 'Cellepora' sp. 1 read 'Cellepora' sp. 1.

Table 3 - continued

Nos. #		G	K	W	S	M	4	5	6	7
202	<u>Lekythopora hystrix</u> MacGillivray	?		?			?	?		
98	<u>Porina gracilis</u> var. <u>tubulifera</u> (MacGillivray)	*	*	*	*		*	*	*	
105	<u>Chiastosella conservata</u> (Waters)	*	*	*	*		*	*	*	
132	<u>Trigonopora vermicularis</u> Maplestone	*	*	*	*		*	*	*	
144	<u>Escharoides duplicata</u> (Waters)	*	*	*	*		*	*	*	
84	<u>Cribrilina hebetata</u> (Waters)	*	*		*		*	*	*	
91	<u>Corbulipora ornata</u> MacGillivray	*	*		*		*	*	*	
114	' <u>Schizoporella</u> ' <u>orbiculifera</u> Canu & Bassler	*	*		*		*	*	*	
36	<u>Oziva concamerata</u> Waters	*	*	*	*	?	*	*	*	
93	<u>Corbulipora cornuta</u> (MacGillivray)	*				*	*		*	
183	<u>Adeonellopsis sulcata</u> (Milne Edwards)	*				*	*		*	
153	<u>Porella otwayensis</u> Maplestone	*			*		*		*	
15	<u>Ellisina profunda</u> (MacGillivray)	*		*		?	*	*	?	
111	<u>Tetraplaria australis</u> Woods var.	*	*	*	?		*	*	?	
1	<u>Tretosina arcifera</u> Canu * Bassler	?		*		*	?	*	*	
83	<u>Arachnopusia unicornis</u> (Hutton)	?				*	?		*	
73	<u>Melicerita angustiloba</u> Woods	*		*		*	*	*	*	*
136	<u>Cucullipora tetrasticha</u> MacGillivray	*		*		*	*	*	*	*
148	<u>Petraliella biincisa</u> (Waters)	*		*		*	*	*	*	*
21	<u>Foveolaria curdiensis</u> Brown	*		*	*	*	*	*	*	*
74	<u>Acerinucleus incudiferus</u> (Maplestone)	*		*	*	*	*	*	*	*
51	<u>Selenaria cupola</u> var. <u>spiralis</u> (Chapman)	*	*	*		*	*	*	*	*
59	<u>Cellaria bicornis</u> (Busk)	*	*	*		*	*	*	*	*
25	<u>Ramphonotus lusorius</u> (Waters)	*	*	*	*	*	*	*	*	*
60	<u>Cellaria contigua</u> MacGillivray	*	*	*	*	*	*	*	*	*
79	<u>Arachnopusia liversidgei</u> (Woods)	*	*	*	*	*	*	*	*	*
97	<u>Porina gracilis</u> var. <u>vertebralis</u> (Stoliczka)	*	*	*	*	*	*	*	*	*
99	<u>Didymosella larvalis</u> (MacGillivray)	*	*	*	*	*	*	*	*	*
126	<u>Hippoporina burlingtoniensis</u> (Waters)	*	*	*	*	*	*	*	*	*
167	<u>Smittinella tatei</u> (Woods)	*	*	*	*	*	*	*	*	*
184	<u>Adeonellopsis varraensis</u> (Waters)	*	*	*	*	*	*	*	*	*
186	<u>Adeonellopsis symmetrica</u> (Waters)	*	?	*		*	*	*	*	*
66	<u>Cellaria rigida</u> var. <u>perampla</u> (Waters)	*	*		?	*	*	*	?	*
35	<u>Aechmella ambigua</u> (MacGillivray)	*		?		*	*	?	*	*
20	<u>Crassimarginatella sculpta</u> (MacGillivray)	*		*		*	*	*		*
172	<u>Tubitrabecularia elevata</u> (Woods)	*		*		*	*	*		*
159	<u>Smittina ordinata</u> (MacGillivray)	*	*		*	*	*	*		*
58	<u>Cellaria australis</u> (MacGillivray)	*	*	*	*	?	*	*		?
5	' <u>Amphiblestrum</u> ' <u>planulatum</u> Maplestone		*					*		
8	' <u>Membranipora</u> ' <u>ancarteri</u> Brown		*					*		

\* Brown, 1958.

Note: No. 1 (line 15). For Canu\* Bassler read Canu &amp; Bassler.

Table 3 - continued

Nos. #		G	K	W	S	M	4	5	6	7
9	' <u>Membranipora</u> ' <u>ancarteri</u> Brown		*					*		
11	' <u>Membranipora</u> ' <u>striata</u> MacGillivray		*					*		
16	<u>Ellisina</u> aff. <u>incrustans</u> (Waters)		*					*		
39	<u>Micropora</u> <u>elegans</u> Maplestone		*					*		
42	<u>Macropora</u> <u>cribrilifera</u> Maplestone		*					*		
70	<u>Cellaria</u> <u>mitrata</u> Brown		*					*		
77	<u>Menipea</u> <u>retroversa</u> Maplestone		*					*		
86	<u>Reginella</u> <u>maplestonei</u> Brown		*					*		
88	<u>Figularia</u> sp.		*					*		
118	' <u>Schizoporella</u> ' aff. <u>tenuilamellosa</u> Canu & Bassler		*					*		
124	<u>Microporella</u> <u>ciliata</u> (Pallas) var.		*					*		
129	<u>Hippoporina</u> aff. <u>bairnsdalei</u> (Waters)		*					*		
143	<u>Plagiosmittia</u> <u>australis</u> Brown		*					*		
164	<u>Smittina</u> <u>rogickae</u> Brown		*					*		
165	<u>Smittina</u> aff. <u>lateralis</u> (MacGillivray)		*					*		
168	<u>Smittinella</u> <u>wataepoolanensis</u> Brown		*					*		
189	<u>Anarthropora</u> <u>voighti</u> Brown		*					*		
191	<u>Vittaticella</u> <u>grandis</u> (Maplestone)		*					*		
14	<u>Ellisina</u> <u>gregsoni</u> (MacGillivray)		*	*				*		
19	<u>Callopora</u> <u>monilifera</u> (Maplestone)		*	*				*		
65	<u>Cellaria</u> <u>biaperta</u> Maplestone		*	*				*		
119	' <u>Schizoporella</u> ' <u>baini</u> Brown		*	*				*		
131	<u>Hippomenella</u> <u>magna</u> Canu & Bassler		*	*				*		
154	<u>Porella</u> <u>rogeri</u> Brown		*	*				*		
162	<u>Smittina</u> <u>uttleyi</u> Brown		*	*				*		
177	' <u>Retepora</u> ' <u>dartmoorensis</u> Brown		*	*				*		
200	<u>Holoporella</u> <u>tridenticulata</u> (Busk)		*		*			*		
28	<u>Hiantopora</u> aff. <u>radicifera</u> (Hincks)			*				*		
46	<u>Lanulites</u> <u>adunca</u> Brown			*				*		
108	<u>Gemellipora</u> <u>auriculata</u> Maplestone			*				*		
133	<u>Trigonopora</u> <u>personata</u> (Maplestone)			*				*		
135	<u>Emballothea</u> <u>angustata</u> Canu & Bassler			*				*		
152	<u>Porella</u> <u>rhomboidalis</u> Maplestone			*				*		
170	<u>Marguetta?</u> <u>geminata</u> Brown			*				*		
194	<u>Stenostomaria</u> <u>solida</u> (Waters)			*				*		
196	<u>Catenicella</u> <u>tenuis</u> MacGillivray			*				*		
197	<u>Catenicella</u> cf. <u>cribriformis</u> Waters			*				*		
142	' <u>Lepralia</u> ' sp.			*				*		
163	<u>Smittina</u> <u>inarmata</u> Brown			*	*			*		
3	<u>Biflustra</u> <u>delta</u> Brown		*		*			*	*	

# Brown, 1958.

Note: No. 9 (line 1). For 'Membranipora' ancarteri Brown read 'Membranipora' pegma Brown.No. 46 (line 29). For Lanulites adunca Brown read Lunulites adunca Brown.



Table 3 - continued

Nos. #		G	K	W	S	M	4	5	6	7
161	<u>Smittina eagar</u> Brown		*		*			*	*	
13	<u>Hincksina geminata</u> (Waters)		*	*	*			*	*	
149	<u>Discopora vultur</u> (Hincks)		*	*	*	*		*	*	
81	<u>Arachnopusia terminata</u> (Waters)		*		?	*		*	*	
55	<u>Crateropora ordinata</u> (Waters)			*	*			*	*	
43	<u>Lunulites rutella</u> Woods			*		*		*	*	
72	<u>Cellaria veteripontis</u> Brown			*		*		*	*	
181	' <u>Retepora</u> ' sp. 3			*		*		*	*	
182	<u>Adeona? armata</u> (Waters)			*		*		*	*	
188	<u>Bracebridgia emendata</u> (Waters)			*		*		*	*	
96	<u>Porina gracilis</u> (Lamarck)			*	*	*		*	*	
17	<u>Caleschara denticulata</u> (MacGillivray)			*		*		*	*	*
34	<u>Aechmella depressa</u> (MacGillivray)			*		*		*	*	*
69	<u>Cellaria myaringensis</u> Brown			*		*		*	*	*
116	' <u>Schizoporella</u> ' <u>submersa</u> Waters			*		*		*	*	*
185	<u>Adeonellopsis obliqua</u> (MacGillivray)			*		*		*	*	*
30	<u>Chaperia cylindrifformis</u> (Waters)			*	*	*		*	*	*
38	<u>Steganoporella haddoni</u> Harmer		*			*		*	*	*
192	<u>Vittaticella</u> aff. <u>insignis</u> (MacGillivray)		*			*		*	*	*
120	' <u>Schizoporella</u> ' <u>suffugium</u> Brown			*		*		*	*	*
140	' <u>Lepralia</u> ' <u>rotunda</u> (Waters)			*		*		*	*	*
104	<u>Chiaestossella daedala</u> (MacGillivray)		?			*		?	*	*
75	<u>Caberea grandis</u> Hincks			?		*		?	*	*
94	<u>Corbulipora pennata</u> Brown				*				*	
113	<u>Lacerna ovalis</u> (Maplestone)				*				*	
122	' <u>Schizoporella</u> ' <u>roberti</u> Brown				*				*	
123	' <u>Schizoporella</u> ' <u>sinudentata</u> Brown				*				*	
128	<u>Hippoporina</u> aff. <u>elongata</u> (MacGillivray)				*				*	
173	<u>Sertella mucronata</u> (Waters)				*				*	
174	<u>Sertella nangeelaensis</u> Brown				*				*	
178	' <u>Retepora</u> ' <u>incisura</u> Brown				*				*	
179	' <u>Retepora</u> ' sp. 1				*				*	
180	' <u>Retepora</u> ' sp. 2				*				*	
190	<u>Vittaticella enormis</u> (Maplestone)				*				*	
195	<u>Ditaxipora internodia</u> (Waters)				*				*	
198	<u>Sphaeropora fossa</u> Haswell				*				*	
4	<u>Conopeum?</u> sp.				*				*	
12	' <u>Membranipora</u> ' sp.				*				*	
23	<u>Odontionella</u> aff. <u>cyclops</u> (Busk)				*				*	
53	<u>Aspidostoma cavatum</u> (Waters)				*				*	

# Brown, 1958.

Table 3 - continued

Nos. #		G	K	W	S	M	4	5	6	7
117	'Schizoporella' <u>filiformis</u> Waters				?	*			*	
29	<u>Chaperia acanthina</u> (Lamouroux)					*			*	
40	'Micropora' <u>carinata</u> Maplestone					*			*	
57	<u>Crateropora</u> sp.					*			*	
62	<u>Cellaria robusta</u> Maplestone					*			*	
85	<u>Cribrilina jonesi</u> Brown					*			*	
102	<u>Gigantopora cribraria</u> (MacGillivray)					*			*	
112	<u>Tetraplaria pedunculata</u> (MacGillivray)					*			*	
175	'Retepora' <u>rimata</u> Waters				*	*			*	*
115	'Schizoporella' <u>macgillivrayi</u> Canu & Bassler				?	*			*	*
47	<u>Selenaria maculata</u> (Busk)					*			*	*
49	<u>Selenaria grandicella</u> Canu & Bassler					*			*	*
80	<u>Arachnopusia liversidgei</u> var. <u>perforata</u> (Waters)					*			*	*
92	<u>Corbulipora elevata</u> (MacGillivray)					*			*	*
109	<u>Gemellipora polita</u> MacGillivray					*			*	*
158	<u>Palmicellaria microporoides</u> Brown					*			*	*
37	<u>Ogiva elongata</u> (Canu & Bassler)				?	*			*	*
26	<u>Nellia oculata</u> Busk					*			*	*
27	<u>Hiantopora intermedia</u> (Kirkpatrick)					*			*	*
31	<u>Chaperia</u> aff. <u>multifida</u> (Busk)					*			*	*
41	<u>Macropora crassatina</u> (Waters)					*			*	*
44	<u>Lunulites canaliculata</u> MacGillivray					*			*	*
48	<u>Selenaria magnipunctata</u> Maplestone					*			*	*
50	<u>Selenaria macgillivrayi</u> var. <u>lucens</u> (MacGillivray)					*			*	*
61	<u>Cellaria enormis</u> Maplestone					*			*	*
63	<u>Cellaria tumida</u> Maplestone					*			*	*
76	<u>Canda fossilis</u> Waters					*			*	*
82	<u>Arachnopusia terminata</u> var. <u>coronata</u> (Canu & Bassler)					*			*	*
90	<u>Acanthocella tubulifera</u> (Hincks)					*			*	*
95	<u>Corbulipora</u> aff. <u>ampulla</u> Maplestone					*			*	*
107	<u>Schizomavella</u> cf. <u>auriculata</u> (Hassall)					*			*	*
110	<u>Tetraplaria australis</u> Woods					*			*	*
125	<u>Hippoporina pertusa</u> (Esper)					*			*	*
127	<u>Hippoporina praetexta</u> (Canu & Bassler)					*			*	*
134	<u>Trigonopora plana</u> Brown					*			*	*
139	'Lepralia' <u>bisinuata</u> Maplestone					*			*	*
141	'Lepralia' <u>orimagna</u> Brown					*			*	*
150	<u>Discopora vultur</u> var. <u>aviculifera</u> (Canu & Bassler)					*			*	*
151	<u>Porella marsupium</u> (MacGillivray)					*			*	*
171	<u>Tubucellaria cereoides</u> (Ellis & Solander)					*			*	*
193	<u>Strophipora harveyi</u> (Wyville-Thomson)					*			*	*
199	<u>Conescharellina cancellata</u> (Busk)					*			*	*

# Brown, 1958.

fidently assigned to either a particular formation or Faunal Unit (i.e. all except Sample 15).

Using the ranges of the bryozoans given in Table 3, it is possible to suggest an age for the doubtful samples 5, 6, 24 and 15 (footnote, Table 2).

- Sample 15 is probably Faunal Unit 5
- Sample 24 is probably Faunal Unit 5
- Sample 5 is probably Faunal Unit 5
- Sample 6 is either Faunal Unit 4 or 5.

Table 3 shows that the formations are Janjukian and Longfordian in age. Further work on bryozoan faunas is needed to extend the distribution table to cover pre-Janjukian and post-Longfordian strata. A start has been made on this by Cockbain (1969) who gave a list of late Eocene and early Miocene species of Cheilostomata occurring in the south of Western Australia.

QUANTITATIVE ANALYSIS OF DISTRIBUTION TABLE

Brown (1958) compared his five faunas statistically, and it is instructive to perform a similar analysis on the revised data. Several methods of comparing the degree of resemblance between

two faunas have been reviewed by Simpson (1960). His preferred method is here called the Simpson faunal correlation coefficient and is calculated as follows:

Cs = C / Nl

where Cs is the Simpson faunal correlation coefficient (0.0 < Cs < 1.0), C is the number of species in common between two faunas, Nl is the fauna with the smaller number of species.

Brown's figures are given in his Table 2 where the highest figure for each pair of faunas is the Simpson faunal correlation coefficient expressed as a percentage. Calculations based on the revised data are given in Table 4A herein. From this table it will be seen that the Myaring Beds (s.s.) still have a low faunal correlation coefficient with the other stratigraphical units and this is in part a reflection of the high number (49%) of species restricted to the unit. The highest faunal correlation coefficient is between the Glenaulin Clay Member and the Koonalunda Lens (Cs = 0.60) which is the same as the percentage of correspondence between the Glenaulin Fauna and the Wataepoolan Fauna of Brown (1958).

TABLE 4  
SIMPSON FAUNAL CORRELATION COEFFICIENTS FOR FORMATIONS (A) AND FAUNAL UNITS (B)

4A

FORMATIONS	Glenaulin Clay Member	Koonalunda Lens	Myaring Beds	Wilkin Beds	Sandford Lime-Stone Member
Glenaulin Clay Member	75 (20%)				
Koonalunda Lens	0.60 (45)	81 (25%)			
Myaring Beds	0.31 (23)	0.20 (16)	87 (49%)		
Wilkin Beds	0.53 (40)	0.52 (30)	0.44 (34)	77 (14%)	
Sandford Limestone Member	0.48 (26)	0.52 (28)	0.28 (15)	0.50 (27)	54 (31%)

4B

FAUNAL UNITS	4	5	6	7
4	75 (20%)			
5	0.73 (55)	119 (34%)		
6	0.37 (28)	0.55 (43)	78 (28%)	
7	0.31 (21)	0.45 (30)	0.48 (32)	67 (40%)

75 = number of species in unit; 0.60 = Simpson faunal correlation coefficient;  
(20%) = percentage of species restricted to unit; (45) = number of species in common.



Simpson faunal correlation coefficients may also be calculated for the four Faunal Units into which the formations are placed and this has been done in Table 4B. This table shows, as would be expected, that adjacent Faunal Units more closely resemble one another than do widely separated ones. On the other hand over half the species occur in only one Faunal Unit:

- 105 species (54%) occur in 1 Faunal Unit
- 56 species (29%) occur in 2 Faunal Units
- 19 species (9%) occur in 3 Faunal Units
- 16 species (8%) occur in 4 Faunal Units

This exclusiveness would suggest that cheilostomatous bryozoans are potentially useful biostratigraphically.

Brown's quantitative analysis of his faunas enabled him to correlate and suggest an age for the fossiliferous samples. However, a comparison of Tables 4A and B shows that faunal correlation coefficients must be treated with reserve because faunas of the same age (for example, Wilkin Beds and Koonalunda Lens with Cs of 0.52) may have a lower faunal correlation coefficient than successive Faunal Units (for example, Faunal Units 4 and 5 with Cs of 0.73).

#### ACKNOWLEDGMENTS

I thank Mr. P. R. Kenley of the Geological Survey of Victoria for generously providing me with the revised stratigraphical framework for the samples and suggesting the new names 'Koonalunda Lens' and 'Wilkin Beds'.

He also made available to me unpublished foraminiferal datings by Mr. D. J. Taylor on some of the samples, and Dr. C. Abele's dating of sample 15. I further thank him and Professor D. A. Brown for reading the manuscript.

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## BILATERAL PRECAMBRIAN CHONDROPHORES FROM THE EDIACARA FAUNA, SOUTH AUSTRALIA

By MARY WADE\*

**ABSTRACT:** A second genus of bilaterally symmetrical Chondrophores has been found in the Late Precambrian at Ediacara Range, South Australia. *Chondroplon bilobatum* new genus, new species, is similar to *Ovatoscutum concentricum* Glaessner and Wade in details of the extreme bilaterality that sets them both apart from previously-described Phanerozoic Chondrophores. The new family Chondroplidae is proposed to contain them.

### INTRODUCTION

The uppermost Precambrian Pound Quartzite at Ediacara Range has attracted worldwide attention for the variety of its fauna and their remarkably good state of preservation. It continues to yield occasional new forms as well as additional (and sometimes very informative) specimens of known species. On a collecting trip in August 1968 two specimens were secured of one of the rarest groups, the Hydrozoan order Chondrophorida. These specimens were a new form and a well-preserved fragment of *Ovatoscutum concentricum* Glaessner and Wade (1966), hitherto known only from its holotype. A small specimen was later found at Braehina Gorge in a fossiliferous deposit equivalent to that at Ediacara (Wade, 1970). The new form is strikingly different from *Ovatoscutum* in shape and in details of its structures but nevertheless shows a much closer relationship to it than to any other genus. These differences and resemblances are taxonomically expressed below by describing the new form as *Chondroplon bilobatum*, new genus, new species, and proposing the new family Chondroplidae to include *Chondroplon* and *Ovatoscutum*.

### ACKNOWLEDGMENTS

I am indebted to Mr. I. M. Thomas, Zoology Dept., University of Adelaide, for supplying comparative material of the modern Chondrophores *Velella* and *Porpita*, and for permission to dissect *Velella*. Professor M. F. Glaessner thoroughly criticized the manuscript, to the great benefit of its final form. My collecting trip was supported

by an Australian Research Grant to Professor Glaessner.

**DEPOSITORY:** The material is deposited in the collections of the Geology Dept., University of Adelaide, Nos. F17335a, b, F17336, and F17338.

### STRATIGRAPHIC POSITION

Ever since the discovery of Precambrian fossils at Ediacara Range it has been known that they occurred just below the top of the Pound Quartzite (Sprigg, 1947). They occupy a zone or 'main fossiliferous unit' about 12 m thick which also contains unfossiliferous strata in various positions and places (Goldring and Cumow, 1967; Wade, 1968). This main fossiliferous unit outcrops around all but the N. side of a syncline which is elongated N.-S.; there the area where it should outcrop is buried under a broad serec. The oldest fossils known from Ediacara Range (Glaessner and Wade, 1966; Wade, 1968) were those of the pennatulacean *Pteridinium cf. simplex* (Gürich). These came from a train of boulders on a hilltop at the southeast of the syncline. As the massive fine-grained sandstone of which they are composed is very rare in the sequence, and they are strung out parallel to the strike of the underlying beds, they were thought to be almost *in situ* and no more than 18 m below the main fossiliferous unit, though their exact position in the sequence was unknown. Their unfossiliferous and rather intermittent equivalents were since found 7 m below the main fossiliferous unit at the S. end of the synclinal outcrop. After tracing this bed over a mile W. and then N. around the syncline, al-

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most to the limit of its outcrop, two further fossils were found, another well-preserved pennatulacean, *Arborea arborea* (Glaessner) and, *in situ*, the large new Chondrophoran float described here.

The second specimen of *O. concentricum* is from the lower bed of the main fossiliferous unit on the NW. side of Gap Creek Fault, opposite Greenwood Cliff. It was not *in situ* but is of characteristic lithology.

Genus *Chondroplon* n.gen.

Type species *Chondroplon bilobatum* n.sp.

DIAGNOSIS: As for type species.

*Chondroplon bilobatum* n.sp.

(Pl. 6, figs. 1-4; Fig. 1)

HOLOTYPE: F17335 a, b, counterparts of a unique specimen.

PRESERVATION: The preserved portions are a negative mould collected *in situ* and the positive mould that fitted into it from above. Owing to differential weathering the specimens partly complement each other's shape. The negative mould shows part of the proximal third of both lobes of a bilobed body (see Pl. 6 fig. 2). The positive mould shows most of the left side and little of the right side (Pl. 6, fig. 1).

The main body of the fossil is inflected by five large, radial folds, with a maximum measurable relief which reaches nearly 1.5 cm on the right side which is the concave side of the now slightly-curved axis. The weathering of the slabs makes interpretation of the five folds difficult. The three on the left side die out before the margin and the more distal right-side fold appears to have done this. The fifth fold is so much the largest that it may have extended to the edge of the disc, but there is a convergence between the flaking of platy weathering that appeared in the field to parallel the little evidence of bedding, and the surface of the fossil. The proximal (see p. 186) right margin and possibly also the right proximolateral margin must have projected into the water for some time after the burial of the remainder of the partly sand-filled float. Its present position indicates the fossil was buried in a generally horizontal position with widely-spaced, upwardly-acute ridges lying radially between the flat earliest chambers and (except for the largest ridge) a considerable distance inside the margin. Perhaps the initial shape was slightly domed, for sharp, radial folds, not symmetrically placed, their more acute angles directed into a chambered body, do not seem explicable as a natural structure. Although the axis is curved and chambers seem to be smaller on the right side than the left at the proximal end (Pl. 6, fig. 1, 2; Fig. 1), it is not possible to tell how much of the proximal right side is lost, or whether, or how much, the convex side of the axis was stretched and the concave side com-

pressed, during burial. The original specimen may have had a symmetrical body throughout growth; preserved portions of the later 2/3 of the chambers are identical. The facts that the large folds in the float reach their maximum on the concave side of the axis, and that the curvature is mainly at the distorted end of the float, support the view that curvature of the axis is fortuitous. The proximal edge is upturned and folded back through 180°, seriously distorting the proximal ends of the earliest chambers. The upward turn of the proximal edge of the float, the curvature of the axis, and the large folds in the float are probably artifacts induced by conditions of burial such as being dragged at by moving water when partly filled and covered by sand. The massive nature of the bed in which it was deposited is quite exceptional in this area. Where broken at the right side, and in several other places, the depositionally upper surface of the float is seen as a mould in the rock. Over much of the area, however, the upper and lower surfaces are separated by a layer of sandstone fill which is cut through by a series of smooth partings that slope proximally from furrows in the upper surface (seen as ridges from the inside) to corresponding structures in the lower surface. This sandstone fill is here described as representing a chambered float with inflated upper and lower surfaces furrowed by depressed sutures. The partings (partitions) between adjacent chamber-fills are moderately to extremely oblique depending on how much the chamber—represented by its fill—has been distorted. In places a reticulate pattern on the positive mould seems to result from the interaction of the two surfaces. This reticulate pattern and most other structures are replicated on the negative mould. Both counterparts have a few features which do not have replicas; these are mainly due to some of the sandstone chamber-fillings having been chipped off the positive mould during natural weathering, thus revealing parts that were previously hidden and removing parts now recorded only on the negative mould. The replication makes it clear that the counterparts are to be regarded as positive and negative counterpart moulds (McAlester, 1962; Wade, 1968). The sloping wedges of sandstone chamber-fills are particularly attenuated near the proximal edge. They record a proximal shift of the lower side relative to the upper side; this may be largely due to the folding back of the proximal end.

DIMENSIONS: The left half of the positive mould is 18 cm long. It lacks only the last few minute distal chambers and the edges of the most proximally projecting chambers. The original length is estimated at about 19 cm. The maximum width from axis to edge is 11.9 cm, so the complete specimen would have been appreciably wider than long if the axis was symmetrically placed. The length along the axis from distal notch to the distorted proximal end is 13 cm; probably 1½ to 2½ cm additional length was involved in the distorted area. The distal notch was about 1.2-1.5 cm deep, suggesting a depth of about 2-3 cm

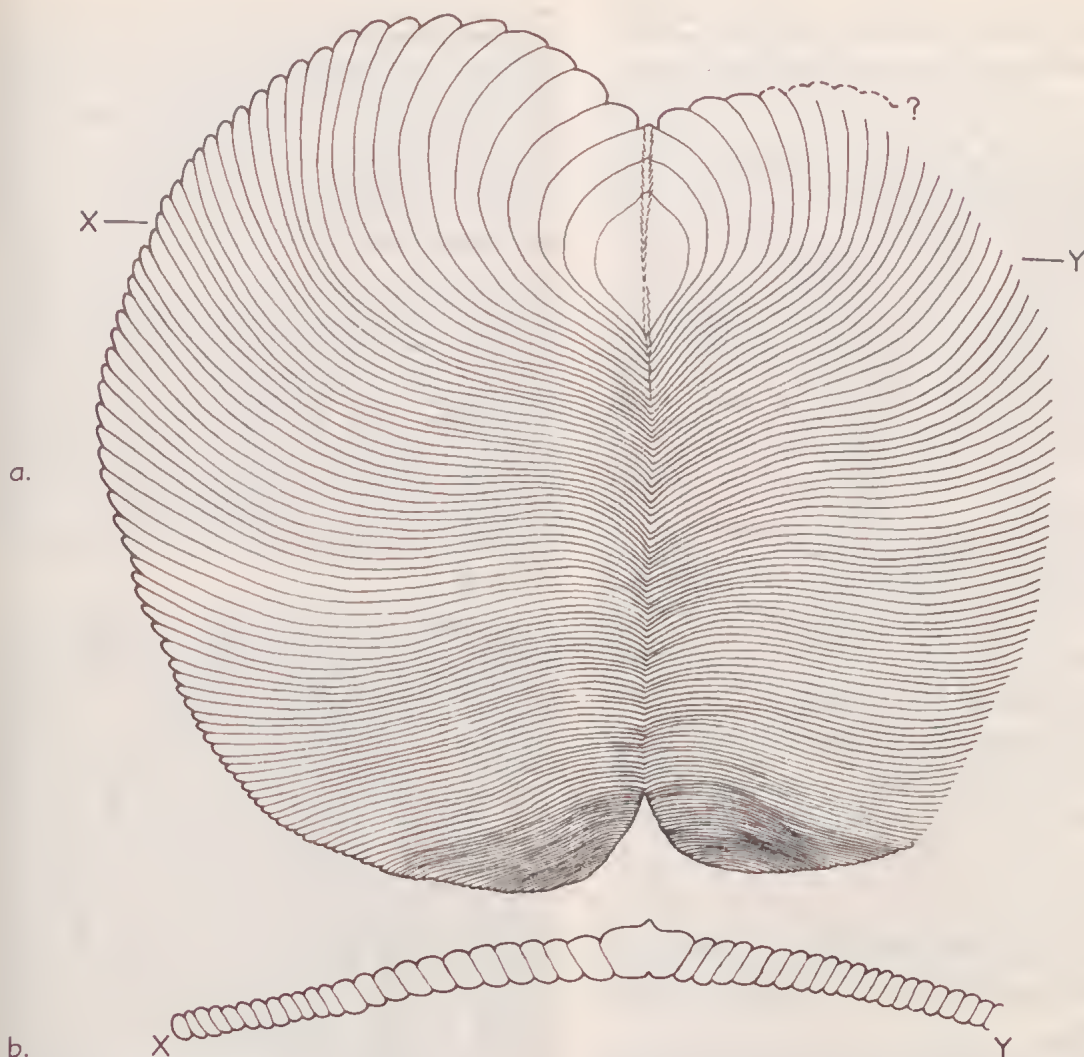


FIG. 1—*Chondroplon bilobatum* n. gen., n. sp.,  $\times 0.6$ . Restored dorsal view, a. and section of float at XY, b. The early chambers appear slightly smaller on the right side than the left but this could be individual variation, as no other asymmetry is indicated by the original material. The ends of all chambers have been restored as simple, rounded lappets like those that frame the proximal notch. The crest on the large initial chamber strengthens towards the proximal notch and was therefore continued across the two annular chambers. Crowding of attenuate late-formed chambers causes darkening of the diagram near the distal notch.

for the proximal notch. The surface is strongly sculptured by over 90 sets of ridges and furrows which indicate chambers and the position of partitions between chambers.

**DIAGNOSIS:** Large, bilobed float with a narrow, strongly-marked axis (developed as a ventral groove and probably a blunt dorsal keel); proximal notch formed at proximal end of axis early in growth (after third chamber in holotype), distal notch formed at distal end of axis late in growth (after 76th chamber in holotype); initial chamber relatively large, rather elongate, pointed distally (undistorted shape of proximal end unknown, but possibly also tapering); early

chambers annular, later chambers progressively less embracing, varying in shape from almost encircling, through crescentic, to slightly sigmoidal half-chambers divided by the proximal notch; chambers higher than broad (where both surfaces visible); individually, chambers narrow toward distal part of axis and broaden away from it, being broadest adjacent to the periphery where they end in rounded lappets; in general, chambers diminish in breadth distally, until very narrow; early chambers increase in length, later length holds constant, and then diminishes; (greatest length of individual chambers reached before widest portion of float in holotype, chambers from about



20th to 40th equally long, greatest width of half float at 43rd chamber); surface strongly ornamented by depressed sutures between inflated chamber surfaces.

**DESCRIPTION:** The fossil consists of two rounded lobes, each more than semi-circular in outline, united along a narrow *axial furrow* (Pl. 6, fig. 1-3). The *initial chamber* is large, over 1.8 cm wide and 2.5 cm long, though the length is doubtful due to distortion. It was probably originally spindle-shaped, and is situated near one end of the axis. This is here called the *proximal end*, both of the axis and the fossil (Pl. 6, fig. 3). The second and probably the third *chambers* are completely embracing, all later chambers are progressively less embracing, leaving a notch between them at the proximal end; this is the *proximal notch*. As the rate of increase in length of chambers was not as great as would have been needed to maintain forward growth of the chambers, the proximal notch widened rapidly; it reached a maximum at the 8th chamber, later chamber-ends retreated distally around the circumference. Maximum chamber-length was reached about the 20th chamber and held constant to the 40th, thereafter it diminished regularly to the 76th chamber, after which a *distal notch* formed at the *distal end* of the axis, halving the chambers and causing the half-chambers to diminish at both ends, that is, much more rapidly. The complex factors of changing chamber-length are superimposed on fairly constant factors of breadth. All chambers are narrowest adjacent to the distal part of the axis and broaden away from it. Overall, they diminish in breadth from first to last. Near the last they are so narrow that they are not clearly preserved because the grain size of the sediment blots them out, but over 90 and probably about 100 were present. The last few mm of the float were weathered away, removing an unknown number of chambers or incipient chambers.

Wherever the peripheral ends of the chambers are preserved they appear to be rounded lappets. Near the centre of the proximal notch the fossil is contorted and stretched, as this portion of the body is folded upward and backward through 180°. Here chamber-ends appear to have been single lappets for each chamber, though very few sutures can be traced around the folded edge to join those delimiting the chambers seen from below. The periphery is present also on the left side and here the lappets are angled distally and appear double, with the depositionally lower portion folded over distally as a D-shaped lappet (Pl. 6, fig. 4). The doubling is interpreted as a probable preservational feature, p. 187.

The main body of the fossil is dominated by the *lower surface* (that which was downward as buried). A cast from the natural mould shows this surface 'ornamented' by furrowed sutures between the chambers which are smoothly inflated in places but elsewhere, particularly where they are broadest, are flat to slightly concave. The positive mould shows structures at 3 levels (Pl. 6, fig. 3): (1) On the

lower surface, appearance as described for the cast from the natural mould. (2) Exposed by chipping, 'concentric' lines formed by the chamber-fillings having been compressed against one another. These fillings grade from narrow prisms (as seen in section on the broken right side) to attenuated flanges of sandstone (Pl. 6, fig. 3a, b). All slope more or less strongly to the proximal end, the partitions and surfaces being almost parallel as the distorted proximal end is approached; in this area the displacement is measurably greater than at 'a' (Pl. 6, fig. 3). Evidently the whole lower surface moved proximally in comparison to the upper surface. (3) The *upper surface* (essentially, an external mould) is exposed 'c', 'd' (Pl. 6, fig. 3). The surface seen at 'c' is a mirror image of any similarly unflattened portion of the lower surface. At 'd' the interior of the first chamber is exposed. In addition to its possible boundaries 'e' and to fortuitous creases it shows a furrow 'f' of the same dimensions as the axial furrow 'g' seen on the lower surface. On the negative mould 'g' ends near a small, oval area at the centre of the initial chamber (Pl. 6, fig. 2).

**RECONSTRUCTION:** As the positive composite mould has parts of both upper and lower surfaces exposed, and elongate prisms to flattened flanges of sandstone between them, it is legitimate to restore it as a thin-walled, chambered structure (float) which was partly filled by sand prior to burial. The apparent axial groove, 'f', seen on the upper wall from inside the initial chamber is deeper than either the apparent thickness of the wall or any restored thickness for it which can be based upon equivalent structures in modern Chondrophores. It thus seems possible that it represents an axial keel on the upper surface. In other words, the upper surface would be the dorsal surface in comparison with later Chondrophores. The evidence for this keel is not conclusive, however, since 'f' could be a fortuitous fold even though it has been shown as a keel on Fig. 1. It extends across the revealed portion of the initial chamber, diminishing toward its centre where it is hidden by chamber-fill, and proximally is lost to view among the creases at the distorted, upturned, proximal edge. The proximal view of the upturned surfaces of the second and third chambers also shows an axial groove; as this does not seem to have been revealed by the weathering away of the chamber fillings, it seems likely that this is the outside view of the lower surface, and that its axial groove extended across probably two annular chambers, to the apex of the proximal notch. The upper surface at the proximal end is more creased than the lower surface seen on the latex cast of the negative mould. While this could be explained as wholly due to the upper surface being on the inside of the curve, there remains a strong probability that the earliest chambers were not only the broadest but the highest, and that the centre of the float was rather peaked, as restored in Fig. 1b. As the second chamber overlaps the first from the left and right sides (Pl. 6, fig. 3) the restoration Fig. 1b shows



some initial slope on the partitions between chambers—but it is not thought likely that even the least-tilted of the partings (Pl. 6, fig. 3) is in the original attitude of a partition. Not enough of the right side of the float is preserved to be certain whether it was bilaterally symmetrical but this is possible even though, on the right, the proximal edges of the first few non-annular chambers are smaller than those on the left. Both sides are greatly distorted. Comparable portions of all the later chambers are identical (Pl. 6, figs. 1, 3).

The minute size of the late chambers (Pl. 6, fig. 1) suggests that simultaneous expansion of numbers of chambers was a growth characteristic, rather than one chamber attaining much of its full size before the next was added. As the later chambers were so small, the float was presumably rather delicate in this area and the distal notch could be considered a post-mortem effect. Against this is the fact that the chambers from the last preserved to the inner end of the notch increase rapidly in length, and probably grew at both ends. The axial line would thus originate as a suture.

The margin is one of the most peculiar structures of the shield. Each chamber appears to end in a pair of flattened lappets, the proximal one folded over and back, and the distal simply folded backward (Pl. 6, fig. 4). These structures are identical in the positive mould and the cast from the negative mould, and provide no unequivocal evidence of whether the appearance of double lappets is original or preservational. As the lappets seen proximally appear to be merely rounded ends to individual chambers, and it is difficult to envisage a changed function (and structure) for lateral lappets when all the float was presumably covered by soft tissue as in modern forms, the possibility of this effect being produced by the conditions of preservation must be considered. That the whole lower surface of the float moved proximally relative to the upper surface is established by the degree and direction of slope of the partings (= partitions) between adjacent chamber-fillings; such a movement would act more strongly on the attached (inner) portion of the protuberant chamber-ends than on their tips, and provides a mechanism that would drag the lower surfaces of all the sand-filled chamber-ends proximally with regard to their upper surfaces, their attached inner ends being the most displaced. This would have the effect of bending the chamber-ends as a whole distally, and tilting them. That such a mechanism acted cannot be validly disputed, but whether it caused the whole of the distal end of the chamber-ends is questionable. It is conceivable that the mechanism described above produced bending of the chamber-ends enough for the general flattening of the fossil to cause them to fold over, their sharply bent walls pinching and dividing their sand fillings (all that now remains) into the more proximal 'lower lappets' which appear folded over and are angled distally, and the more distal 'upper lappets' which are merely angled distally. It is thus not necessary to assume that the

double lappets are an original structure while waiting the proof of further specimens.

REMARKS: The possession of notches at either end of the axis distinguishes *C. bilobatum* from any other Chondrophore. Its characteristic of steadily less embracing chambers is also unique. Its axial structure is much more definite than the symmetrically placed axis of *Ovatoscutum*, presumably because of a differing mode of growth. The axial line of *Ovatoscutum* makes no more impression on the chamber surfaces than the 'E.-W.' sulcus of the lateral vascular vessels of *Veleva* or *Plectodiscus* Ruedemann (Caster, 1942). The association of this axial line with the notch and the bisymmetrical chamber shape, however, indicates that it is not a pair of lateral canals. This emphasizes the basic bilateral symmetry of *Ovatoscutum* (and *Chondroplon*), while the lack of a raised centre and sail also differentiates it from *Plectodiscus*.

The available evidence for *C. bilobatum* (Pl. 6, figs. 1-3) suggests the action of compression on depressed sutures and smoothly-inflated chamber surfaces as the cause of its ridged ornamentation which is now closely similar to the 'concentric' ornamentation seen on the holotype of *Ovatoscutum concentricum*, Glaessner and Wade. This resemblance is almost certainly superficial, as the new fragmental specimen of *O. concentricum*, much less flattened than the holotype has steep-sided, round-topped ridges marking the position of sutures between chambers which have flat surfaces. Relics of this condition are also seen on the less-flattened portions of the anterior chambers of its holotype. The small individual had very narrow ridges between its flat-topped chambers (Pl. 6, fig. 5). Its axis and other characters are as described for the holotype (Glaessner and Wade, 1966). Sclerotization probably diminished posteriorly, for the definition of chambers ceases in an irregular manner as in the holotype, leaving a wide, posterior notch after about 10 chambers.

To compare *C. bilobatum* with *O. concentricum*: both have a narrow axis, and in both individual chamber-breadth is greatest adjacent to the axis at one end and smallest at the other. The end of the axis where chambers are broadest was designated 'anterior' in the description of *O. concentricum* (Glaessner and Wade, 1966). The term 'proximal' (used here for description of *C. bilobatum* where this end is formed prior to the opposite or distal end) is preferable as the Chondrophores lack an anterior and a posterior definable in terms comparable to general usage in invertebrates; their major structures are radially symmetrical except in those forms that have a sail, and even in these, the sail is the main deviant structure. There is an obvious difference in structure between the two forms in that notches are formed at both ends of the axis in *C. bilobatum* and only at the distal end in *O. concentricum*. The distal notch forms late in growth in *C. bilobatum* and relatively early in *O. concentricum*. In this form the curvature of the chambers from the proximal part of the axis to the distal notch changes from crescentic

inwardly, to nearly parabolic toward the outer edge. The new fragment is of a large specimen; though only the outer part of one side is present the possession of a distal notch can be inferred from the parabolic curve of its chambers. The proximal notch of *C. bilobatum* is formed after only two annular chambers and all succeeding chambers are progressively less embracing. The distinction between this character and the proximally complete chambers of *O. concentricum* would not be greatly affected by the discovery of further specimens of *O. bilobatum* with more or less than 2 annular chambers; it depends on a complex interplay of growth factors. While in *C. bilobatum* the breadth and the degree of embracement constantly diminish, the length of individual chambers first increases, then remains constant, and finally diminishes. In contrast, both the breadth and length of chambers increase throughout in *O. concentricum*, though the rate of increase in length may drop off as the shape of chambers tends towards parabolic. It is remarkable that a distal notch is found in both genera when their antithetic growth-form is the basis of one of their greatest differences. The initial chamber is large in *C. bilobatum* and very small in *O. concentricum*.

The order Chondrophorida was described as consisting of two families, the Porpitidae with strictly radial pneumatophores and the Velellidae with less strictly, but still dominantly, radial pneumatophores. The Late Precambrian bilateral forms fit neither of these families and should be classified in a family of their own.

## Order CHONDROPHORIDA

### Family CHONDROPLIDAE nov. fam.

#### Type genus *Chondroplon* nov. gen.

DIAGNOSIS: Float bilaterally symmetrical about a narrow axis. Chambers individually broadest toward one end of the axis (proximal end) and narrowest adjacent to the opposite (distal) end. With a distal notch dividing the later chambers axially, with or without a proximal notch. Initial chambers large or small, later chambers decreasing or increasing in breadth and length.

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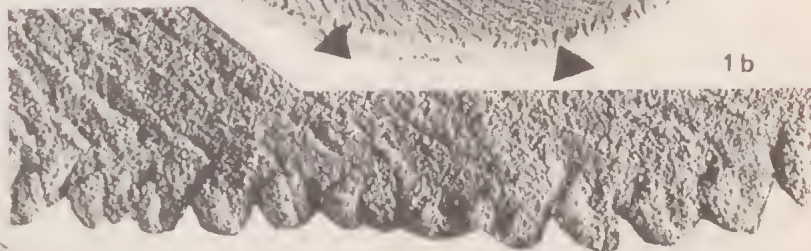
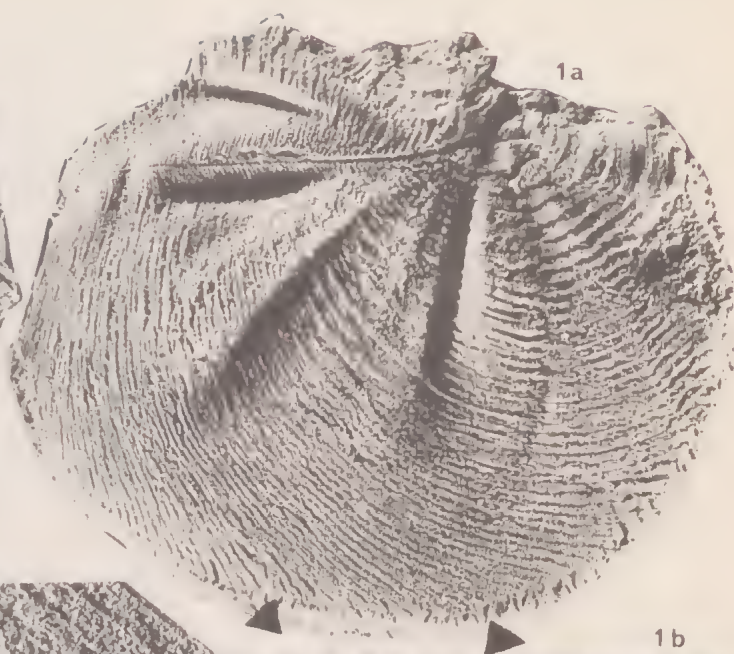
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## EXPLANATION OF PLATE 6

(All photos unretouched. The proximal ends of all specimens are to the right except in fig. 2.)

- FIGS. 1-3—*Chondroplon bilobatum* nov. gen., nov. sp. F1735a, b. 1a)  $\times 1$ , the positive mould of the float, 1b)  $\times 1.95$ , the margin between the pointers on 1a. 2)  $\times 1.4$ , the negative mould. 3)  $\times 1.4$ , the proximal end of the positive mould; a, chamber-filling exposed between lower surface and upper surface, b, flattened flanges of sandstone representing chamber-fillings; c, upper surface of float chambers; d, upper surface of initial chamber; e, suture around initial chamber; f, possible axial structure of upper surface of initial chamber; g, axial structure of lower surface.  
 FIGS. 4, 5—*Ovatoscutum concentricum* Glaessner and Wade, F17336, F17338, respectively. 4)  $\times 1$ , fragment of external mould with depressions representing sutural ridges, natural edge at top. 5)  $\times 1.25$ , complete small specimen from Brachina Gorge (latex cast).









## EDITORIAL FOREWORD

*In Part 1 of this Volume the current format of two columns per page was introduced to supersede the previous style. This has drawn some unfavourable comments, but predominantly members have expressed approval. Further slight innovations are made in this Part, and Members' opinions of these are invited.*

*Council has felt that a statement outlining the Society's publication policy would be helpful to potential authors and this has been included as an introduction to the Instructions to Authors, which are printed in full in this Part (pp. 271-273). Normally the Instructions to Authors will appear in abstract only in each Part: copies in full may be obtained from the Executive Officer.*

*It is of prime importance that papers contain ideas and information of interest to members while at the same time maintaining generally recognized standards of presentation. The Publication Committee of the Society welcomes suggestions directed towards meeting these two requirements.*

*A new section dealing with Short Communications is introduced in this Part with the publication of a paper by Mr. E. D. Gill recalling the early historical development of some sciences in Victoria. It is intended that this section, Short Communications, accommodate articles and reports that contain information or routine data of interest to members, but which do not make an effort to integrate the data into general sets of principles. Some examples of the types of brief reports that might be included in this section are biological check lists, announcements of radio-metric dates and book reviews.*

*A special feature of this volume is the inclusion of an author index to all papers published in the Proceedings, 1959-1971. This was drawn together by the Executive Officer, Dr. R. R. Garran.*

J. W. WARREN  
Hon. Editor



THE FLOODS IN MELBOURNE.—VIEW FROM PRINCE'S BRIDGE.

[FROM A SKETCH BY OUR SPECIAL ARTIST.]

FRONTISPIECE: Reproduced from *The Illustrated Melbourne Post* January 25, 1864, this 'sketch' furnishes a vivid contemporary impression of the flood of December 1863 (see Article 20, p. 197). 'Communication by road with Emerald Hill and Sandridge was for a whole week suspended', the accompanying news item states, 'and the railway line connecting these townships with the city has also been completely inundated . . . The boats seen crossing the water were used, after the first fury of the deluge subsided, to convey passengers and goods to Emerald Hill.' (Emerald Hill is the old name for part of South Melbourne, and Sandridge for Port Melbourne.)



# THE FAR-REACHING EFFECTS OF QUATERNARY SEALEVEL CHANGES ON THE FLAT CONTINENT OF AUSTRALIA

By EDMUND D. GILL\*

Presidential Address 1970, Royal Society of Victoria

**ABSTRACT:** Major changes of sealevel have resulted from changes in the world ice budget. Australia even in the Ice Age had little ice, but of course is affected by the global eustatic changes. Indeed, it has been affected more by reason of being the flattest of the six continents.

Trees in position of growth under the sea, freshwater peats, relict sediments and buried channels on the continental shelf bear witness to changes of sealevel. The stratigraphy and chronology of the Yarra Delta, Victoria, are used to illustrate this. Eustasy in relation to tectonics, ecology and sedimentation is discussed.

## INTRODUCTION

So ingrained is the concept of the last Ice Age in the literature of a number of scientific disciplines that the knowledge of this major world event seems to have been with us always. However, it is only about 130 years ago (Darwin 1887, 1: 250) that the idea was first put forward as a scientific proposition. Such was the magnitude of this new concept, and so far-reaching its implications, that some eminent scientists of the day could not accept it. Darwin did, but Elie de Beaumont did not. The sediment of present rivers was then called the Alluvium, while the 'superficial drift' of the Ice Age was named the Diluvium.

It was soon realized that one of the major effects of the Ice Age was drastically to alter sealevel, thus changing the shape and extent of continents, creating land bridges across which plants and animals could migrate, altering by climatic change the distributions of soils, plants and animals (including man) across the world, turning estuaries into valleys, and continental shelves into extensive coastal plains. We are still in the Ice Age; we live in an Interglacial. Thus, although the sea has been higher than at present, most of the range of sea-level change lies below the present level.

Modern man is an Ice Age animal, adjusted to the exigencies of this unusual Era. The older genera of men such as *Australopithecus* go back into the late Tertiary, but *Homo* is an Ice Age genus, albeit first evolved in the warm continent

of Africa. All men now belong to the one species, which we have called *Homo sapiens*. This is not a boast, but a reference to the fact that man alone is self-conscious and a thinker. Sir Julian Huxley (1957) was so impressed with the significance of this that he made man a separate Kingdom, the Psychozoa.

## WORLD ICE BUDGET AND SEALEVELS

Ice was of course the characteristic product of the Ice Age. What amazed the first discoverers of the Ice Age was that great glaciers and ice caps had extended down over Europe and North America, so that many prosperous countries would then have been but huge ice fields. It was not realized at first that the fertility of those countries arose from the fact that the ice lobes and glaciers, like giant bulldozers, had swept away the older leached soils, allowing their replacement by young, rich soils.

In due time the existing volume of ice was calculated, and the amount of ice generated in the last stage of the Ice Age estimated. When the great ice caps melted, the water ran into the sea, and so sealevel rose. Thus there was developed the idea of the ice budget, i.e., the mutual relationships of world ice volume and seawater volume. A great deal of water is carried in the atmosphere, but calculations show that this factor can be neglected, because the condensation of all water

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from the atmosphere (an extreme that would never happen) would raise sealevel only 3.7 cm. Indeed nearly all the water on this planet (97.6%) is in the oceans. Although only 1.7% of this is contained in existing ice, the melting of this ice would raise sealevel enough to drown London, New York, Melbourne and hundreds of other cities.

The changes of sealevel brought about by changes in the ice budget are called eustatic, or more precisely glacio-eustatic; the principle involved is called eustasy (Gill in Fairbridge 1968). Until the 1950s there were many doubts about glacio-eustasy, e.g.

1. Were the advances of the glaciers (increase of ice volume) and the lowering of sealevel really synchronous?
2. Were the glaciations in the northern and southern hemispheres synchronous, or did they alternate?

Such alternation would of course affect the degree of sealevel change. These were problems of chronology, and the means to solve them became available in 1950 with radiocarbon dating. The results have dispelled all doubts. As the glaciers advanced, sealevel rose. The effects were global. Apart from relatively small local effects such as would be expected, the whole system is synchronous throughout the world. These processes are still active, but over the past 6,000 years on a subdued scale (Fairbridge 1961).

Another problem arising from the study of the ice budget concerned the role of the Antarctic ice cap, since the volume of ice on Antarctica was unknown. During the International Geophysical Year work to determine this was initiated, and now a number of bores has been sunk through the ice, and a number of geophysical traverses have been run. For the first time, reasonable estimates of present and past volumes of ice in Antarctica have become possible. Professor R. F. Flint (in press) of Yale University has recalculated the world ice budget, including Antarctica, and the results are as interesting as they are surprising. There are many assumptions in such calculations, but they are at such a stage that they appear to be of the correct order. Professor Flint considers his results are minimal quantities. His figures show that 89% of the world's present ice is in the Antarctic Continent, and most of the remainder in Greenland. If the world's ice were melted, the volume of water resulting would be  $24 \times 10^6 \times \text{km}^3$ , the water volume being calculated as 92% of the ice volume. This amount of water would raise sealevel by 65 m. Calculation of the volume of Ice Age ice

gives a minimal reduction of sealevel of 132 m apart from any isostatic effects. Geologic evidence from the sea floors suggest the sea dropped lower than this figure, supporting the conclusion that the figure is minimal.

It is thus clear that sealevel at the present time can be affected more by changes in the Antarctic ice cap than by changes in any other ice accumulation. This ice cap dominates the ice budget. Even if the calculations were out by as much as 20%, this would still be true. However, as climatic change affects the whole globe, large changes limited to Antarctica are not to be expected. The next largest ice mass is Greenland with 9.8% of the present ice volume. Antarctica and Greenland therefore possess (on present calculations) 99.1% of the world's ice, but the position was different in the Glacial Stages. Then the huge Scandinavian (17%) and North American (38%) ice sheets came into existence, and made up more than half of the world's ice volume (55%). The reason for so much ice remaining now on the Antarctic continent is its position as a land mass at the pole (in the northern hemisphere the Arctic Ocean occupies the polar region), and much of it consists of a high plateau. Thus the northern hemisphere ice sheets provided the majority of the water that lifted sealevel from the Last Glacial low to the present, viz. North America 38% of the Glacial Stage ice and Scandinavia 17%, making 55%. Antarctica provided 33%, making a total of 88%.

Even in the Ice Age Australia had little ice, because it is the flattest continent with no high mountains, and it is also the driest continent, with restricted precipitation. Nevertheless, the shorelines of Australia, like those of the rest of the world, were affected in a major way by the eustatic changes of sealevel. Indeed, they were more affected, because of the flatness of the continent (Fig. 1). If the Ice Age had been discovered first in Australia, it would have quite a different name because of the absence of ice. Perhaps it would have been called The Age of Changing Sealevels.

## CONTINENTAL SHELF

Round all continents there is a submarine platform—the continental shelf. Indeed, it is more significant to think in terms of the continental terrace (the continental shelf plus the coastal plain) because the coastal flats are themselves in part a product of the higher sealevels. On this view, the outer edge of the continental shelf is the real border of the continent. Certainly, present sealevel has little significance in long term. It is ephemeral even from the point of view of the last 15,000 years. Until recent times man has looked on the mountains and the levels of the seas as





FIG. 1—Tasmania, the Australian mainland, and New Guinea, showing the connecting continental shelf that became land during low sealevels, permitting migrations of plants and animals (including man).

permanent, but neither are. The proved mobility of the land infers changing levels of the sea, quite apart from glacio-eustasy. However, the eustatic effects on sealevel are very rapid compared with the tectonic effects. Coastal geomorphology was long a problem until the present eustatic views were adopted. Features of both emergence and submergence were found on the same coasts.

During the time man has been on the earth, sealevel has been at or near the edge of the continental shelf a number of times, and also higher, covering the areas now occupied by coastal cities. However no human record has been retained of these things, because the changes have been masked by two factors: (1) the constantly changing level of the sea due to diurnal tides, and (2) the short life of a man compared with the time range of these changes.

The tides rise across the shore generally twice a day (or more precisely twice each lunar day) and erode the edge of the land, forming beaches and cutting shore platforms. With a very much longer frequency in the Quaternary (perhaps of the order of 50,000 years), the oceans have swept across the borders of the continents and back again, modifying the continental terraces by trimming the bedrock and distributing sediments. The major tool for performing this work is the power-

ful surf-zone. Its effectiveness is greatly increased because the transgressions and regressions of the sea are not smooth, but a series of oscillations. The surf-zone is like a rasp that is the more effective because rubbed to and fro across the surface it is abrading. Climatic changes are a complex of smaller cycles superimposed on larger ones, and since the ice-budget is presently the dominating factor in sealevel change, the complex variations in climate are reflected in complex oscillations of sealevel.

As would be expected, the outer edge of the continental shelf is not perfectly regular, but it occurs at a depth of about 200 m. Also, the shelf varies greatly in width. Thus in Australia it averages 22 km off the coast of N.S.W., but reaches 320 km on the NW. coast of the continent. The range of width of shelves round the world is 1-1,200 km. Because Australia is such a flat continent, the flooding of its terrace by the postglacial rise of sealevel is very extensive. Australia has the third largest area of continent shelf of all the countries of the world. During the Last Glacial, Australia had a land mass one-third larger than it is at present. At that time it had an extra 2,600,000 km<sup>2</sup>. To the north, the Sahul Shelf was dry. There was no Torres Strait or Gulf of Carpentaria; most of the Arafura Sea was dry. New



Guinea was an extension of the mainland. Tasmania was a peninsula, and Kangaroo Island a promontory. The Great Barrier Reef area was a coastal plain. Likewise the islands and reefs along the W. coast were a coastal plain. To the NW. of the continent, the Sunda Shelf was dry, making Borneo, Indonesia, and the numerous smaller islands of that area a part of continental Asia. Crossings from Asia to Australia of many forms of life (including man) were greatly facilitated because the distance was shorter and the landfall more convenient. It is likely that the first migration of Aborigines to Australia occurred at such a time of low sealevel. The last low was 18-20,000 years ago, but good evidence is now available for Aboriginal occupation up to 32,000 y. BP, so they definitely crossed before the last low. The previous low level was about 60,000 y. BP, so that is a theoretical possibility for the time of first Aboriginal migration. This figure is twice the present demonstrable antiquity of the Australian Aborigines.

## LEGISLATION ON THE CONTINENTAL SHELF

For a long time geologists have pointed out that the edge of the continental shelf is the real edge of the continent, that a number of times in the past this has been the actual shoreline, and that in this zone there occurs the transition from continental to oceanic crust. Interest is now shown in this concept by legislators because the shelf has become an economic issue. Oil has been discovered and exploited on many continental shelves of the world. The rivers entering the sea at the present coastline once ran right across the shelf and debouched at its margin. These rivers then carried gold, tin, rutile, diamonds, and other minerals useful to man to sites on the continental shelf. The powerful surf-zone of transgressive and regressive seas concentrated some of these minerals in ancient beach and shallow-water marine deposits. The technology is now available for their exploitation.

While not attempting to disturb the earlier concept of the high seas, or that of international air space, the United States has declared that it regards 'the natural resources of subsoil and the sea-bed of the continental shelf beneath the high seas but contiguous to the coasts of the United States as pertaining to the U.S., subject to its jurisdiction and control'. Similar declarations have been made by the Governor-General of Australia with respect to the continental shelves of Australia and New Guinea. Largely due to Australia's efforts, the definition of 'natural resources' has been extended to include certain living resources

such as pearl shell, *bêche-de-mer*, and other 'organisms . . . on or under the seabed'. The study of the Australian continental shelf is now proceeding in order to discover what advantage can be taken of the deposits resulting from Quaternary changes of sealevel. However, the legal problems are complex (O'Connell 1970).

## EVIDENCE THAT THE CONTINENTAL SHELF WAS DRY

1. *Trees in Position of Growth Below Sealevel.* Such have been reported in numerous places round the world, and for the present purpose some from SE. Australia will be cited. At Badger Head Bay in N. Tasmania (Edwards 1941) there are two bold headlands of hard rocks protecting a sandy beach nearly 6 km long. Three outcrops of peat and peaty sand protrude through the beach, and were examined by Mr. M. R. Banks and myself in 1958. The two outcrops in the middle of the bay contain in situ stumps of possibly tea-tree and *Banksia*. Specimens brought back for determination were too collapsed to permit certain identification. The stumps seen by us were below mean sealevel, and the tidal range was estimated at 2-2.5 m. Behind the beach is a sand ridge protected by a layer of storm-laid pebbles. Radiocarbon assay of stump wood gave an age of  $7,380 \pm 100$  y. BP (N.Z.). Relative rise of sealevel has brought the beach up over the former swale deposit. No evidence could be found of tectonic movement in this region in the past 8,000 years, and stumps of this age are known in many places round the world on or near the shore, so the displacement is probably eustatic. A similar 'drowned forest' occurs at Port Sorrell (also on the N. coast of Tasmania), and on Cape Barren Island in Bass Strait.

When the Captain Cook Graving Dock in Sydney, N.S.W., was being excavated about 1940, the stump of a large tree was found in position of growth (Fig. 2) about 14.6 m below sealevel. Although it is not known for certain to what level of the fossil stump this depth was measured, those concerned think the depth was to the floor of the Dock as seen on the right side of Fig. 2. A piece of a large root about 15 cm in diameter was supplied for radiocarbon dating by Mr. C. L. Hoffmann of the Forestry Commission of N.S.W. Mr. H. D. Ingle of CSIRO Division of Forest Products determined the wood as probably *Eucalyptus gummiifera* (bloodwood). As it would be useful to know the time of the death of the tree, thin slivers of wood were taken from the outside of the root as being the sample that would give a date nearest to this time. Dr. T. A. Rafter of the New Zealand Institute of Nuclear Sciences assayed



FIG. 2—Drawing by George Browning from a photograph taken during construction of the Captain Cook Dock, Sydney, N.S.W., showing a *Eucalyptus* stump in position of growth, with a drain cut below it. Radiocarbon age of outermost wood was 8360 y.

the sample, determining the age as  $8,360 \pm 110$  y. BP. As the stump was in position of growth, it could not grow at that level unless it were out of contact with sea water. At the time of the death of the tree, the sea must therefore have been at least 3 m lower, viz.  $-18$  m, because the tree was a large one. The wood of the root sample supplied is excellently preserved, and so must have been buried not a great time after the death of the tree. There is evidence that some decay took place in the sap-wood before the tree was submerged, but this is to be expected on the accepted rates of sealevel rise. The wood of the eucalypt tree in position of growth, 19 m below sealevel, at Spencer Street, Melbourne, is likewise very well preserved. The carpenters who worked it stated that it seemed no different from present-day timber except for a slight smell of hydrogen sulphide. The fairly common occurrence of tree stumps round the world from present sealevel down to about 30 m is a function of the rapid rise of sealevel during the Flandrian Transgression. Bores put down in Hobson Bay between

Williamstown and the Gellibrand Light penetrated up to 4.3 m thickness of wood. This is interpreted as indicating a fossil forest buried beneath the sediments of the bay, and with some trunks still standing.

Etheridge, David and Grimshaw (1897) described a geological section of Shea's Canal, Sydney, N.S.W., that showed a fossil dugong about 1 m below LWL, and tree stumps just above and just below a disconformity 3 m below LWL (Fig. 3). Aboriginal stone axes were found approximately at the levels of the stumps.

In Melbourne, difficulty was experienced in building the Spencer Street bridge over the River Yarra in that, while on the N. bank there was a sound foundation of Pleistocene basalt, the S. abutment had to be built in deep late-Quaternary sediments of poor bearing-strength. As such estuarine sediments are notoriously variable, the engineers put down bores about every metre so that there would be no surprises. But there was a surprise in the form of a river red gum stump in position of growth 19.2 m below LWL. The bores



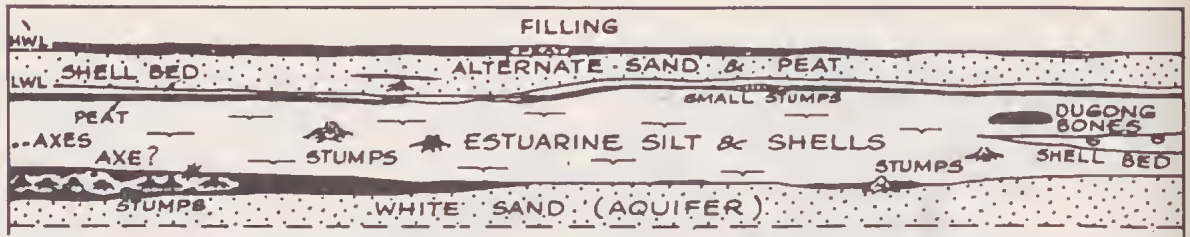


FIG. 3—Section of Sheas Creek Canal, Sydney, N.S.W., 6.6 m high and 660 m long (adapted from Etheridge *et al.*, 1897) showing Flandrian sediments with tree stumps below the present level of the sea.

had penetrated between the roots and missed the stump of the trunk, which was 1.2 m in diameter. The edge of the large cylinder used in emplacing Foundation No. 1 rested on the stump, which had to be removed.

As the stump was large, the tree had been growing there a long time. During that period at least, there could have been no salt water at the roots. As LWL is the datum on all the published plans of this bridge (Chapman 1929) it is presumed that the level given for the stump of '—63 ft' was measured therefrom; also as the work was held up by the cylinder resting on the top of the stump, and this is the only flat surface to which measurement could be made, it is assumed that the 19.2 m was measured to this level. If so, the position of the stump is as shown in Fig. 4, in a bed of peaty sediment accumulated on the swampy floor of this river channel. After the valley was cut, the river was diverted, otherwise such sediments could not accumulate. They continued to accumulate after the tree died, because the stump was covered by them. At 'the level of the stump' a layer of the moss *Sphagnum cristatum* was found, proving freshwater conditions, and suggesting a colder climate than at present since this moss now lives on the high plains. In this bed fossil pollen and the elytron of a beetle were found (Gill 1955). The diatoms recovered at this depth during the extension of the Breakwater Pier at Williamstown also indicate colder conditions. Such would be expected with sealevel as low as this. Radiocarbon dates of 8,300 and 8,700 years have been obtained for pieces of the stump, while the moss dated 8,330 years. The peaty bed in which the stump occurred is draped over the steep sides of the valley (Fig. 4) as well as over its floor, so the river flowed elsewhere. Evidence is given later that one course was under where the new Art Gallery is built, which accounts for the foundation difficulties experienced with that site.

**2. Freshwater Peats.** As such peats are the product of freshwater plants, their occurrence below sealevel is good evidence for changed relationships of land and sea. Peats are common

under beaches and barriers, and in estuaries, while many have been discovered on the continental shelf. When the shelf is better known, reported occurrences will undoubtedly be more numerous. Submerged freshwater peat bogs off the coast of U.S.A. have been reported by Emery and Milliman (1971). They have been sampled to 68 m below the surface of the sea, and their radiocarbon dates extend to 15,000 years ago.

Fossil pollen from these peats show a succession from tundra, spruce, pine and oak, according to their degree of association with retreating glaciers (Emery *et al.* 1967). Other examples of non-marine peats now below sealevel are those described from the Netherlands by Jelgersma (1966), from Florida by Scholl and Stuiver (1967), from Bermuda by Neumann (pers. comm.), and from New Zealand by Suggate (1968).

**3. Relict Sediments.** Coral and algal reefs below the level at which they can now form, beach rock and shallow water shellbeds far out under the sea, widespread layers of sediment on the continental shelf out of context with present deposition, shallow water oolites under the deep sea, submerged sand ridges and aeolianite dunes, drowned archaeological sites, and the numerous teeth and bones of land animals found on the continental shelf are all evidence of the changed relationships of land and sea. Dill (1968) has recorded deeply submerged terraces and low sea cliffs on the continental slope of Southern California, Baja California, Mexico and Australia. Maxwell (1968) has described relict sediments on the Queensland continental shelf. Phipps and Shirley obtained shallow water marine shells from the outer continental shelf of N.S.W. at a depth of 128 m (70 fm), which gave a radiocarbon date of 12,900 years (Gill 1967).

**4. Buried Channels.** The lowering of sealevel had a profound effect on the river systems of the world. As base level was so drastically and rapidly lowered, all the streams were rejuvenated. They cut down deeply into their channels and worldwide, except where the rocks were very soft,



carved river gorges. Conversely, when sealevel rose again, the channels so cut were infilled with soft sediments. Continuous seismic profiles have revealed some of these buried channels. One of the best known is the Hudson Channel off the NE. of North America. There is ample evidence that the same process occurred in Australia, but the channels have not been very closely studied as yet. However, some of these changes have been traced in the vicinity of major cities because they have resulted in major foundation problems during the construction of harbours, bridges, and heavy buildings. We will use the Yarra delta in Melbourne, Victoria, to illustrate the effects of the changes in sealevel.

### THE YARRA DELTA

The present Yarra delta covers about 90 km<sup>2</sup>. Its base is the kaolinized Tertiary Nillumbik Terrain of Silurian bedrock and Oligocene river sands

and basalt, which has been flexed (Melbourne Warp) under Port Phillip Bay (Gill 1961, Bell *et al.* 1967). Two outcrops of Oligocene basalt (the South Melbourne hill, and a band from the River Yarra to Essendon) form a linear block oriented NW.-SE. fronting the Silurian ridge on which the central part of Melbourne is built (Fig. 5). This ancient basalt has been stripped off the Silurian ridge, and its present outcrop is actually the edge of a plate that continues under the delta, where it has been eroded during Quaternary low sealevels (Fig. 6). Bore through the basalt shown in Fig. 6 proved that there are two flows separated by carbonaceous sands. Pollen analysis by Dr. Isabel Cookson revealed taxa similar to those in the Altona and Yallourn brown coal, and hence the basalt is given an Oligocene age, but an older age is possible. Above the basalt there are four Quaternary formations (Fig. 7):

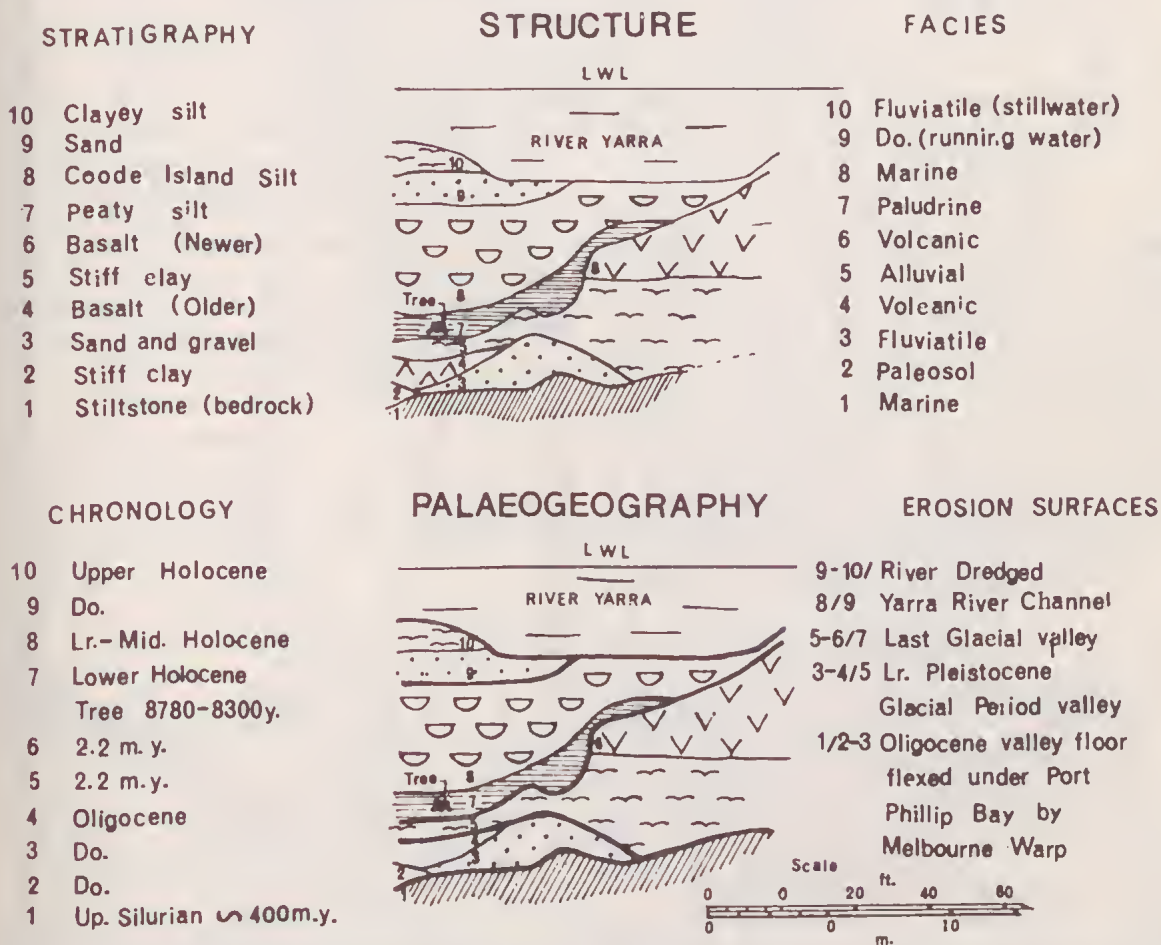


FIG. 4—Section of the S. abutment of the Spencer St. Bridge over the Yarra R., Melbourne, Victoria, showing a *Eucalyptus* stump *in situ* below present sealevel and covered by Flandrian sediments. The stratigraphy and chronology are summarized. Based on Chapman 1929.

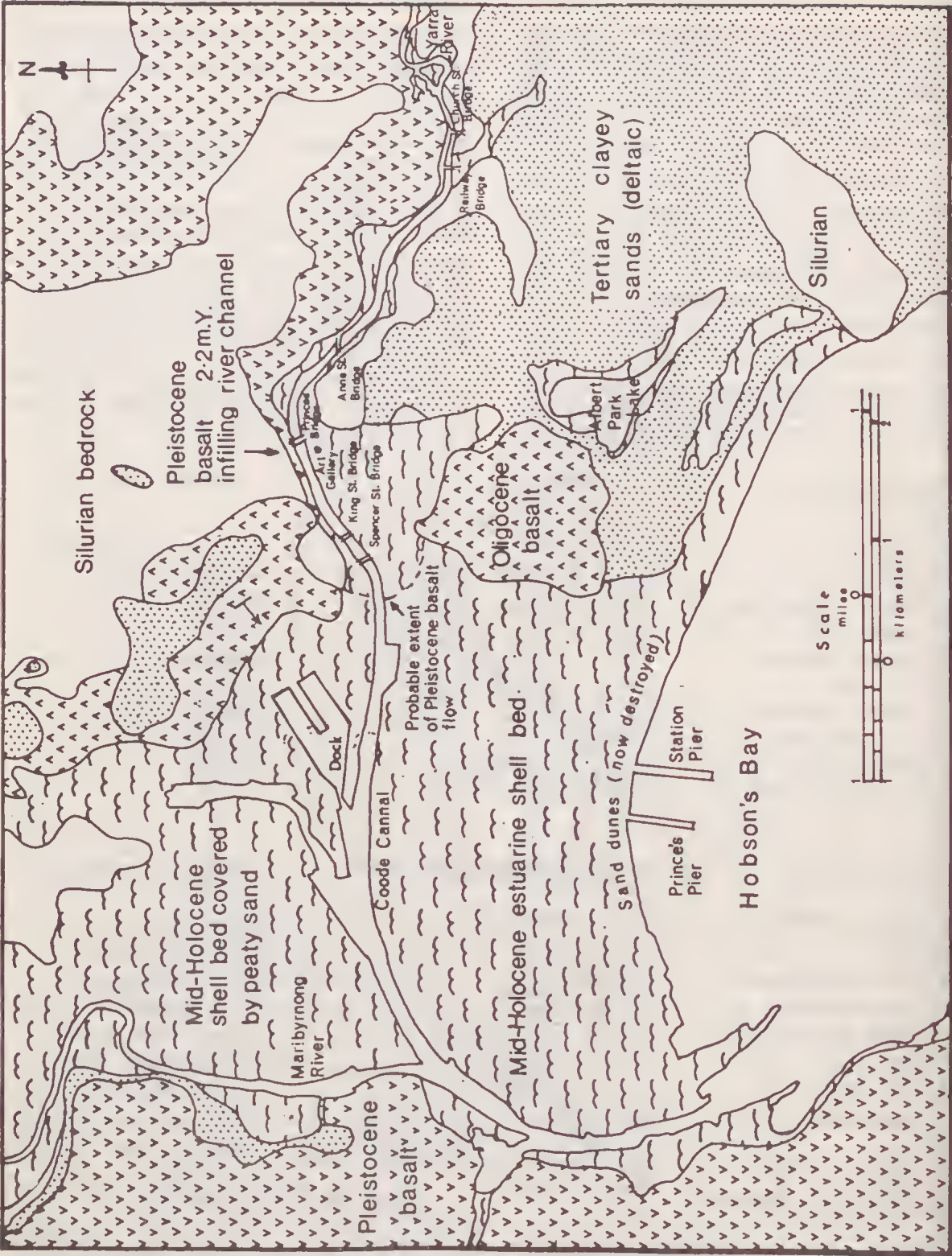


FIG. 5.—Geological map of the Yarra R. Delta, Melbourne, Vic., showing the distribution of the formations, and the localities referred to in the text. Based on Geological Survey of Victoria map.



<i>Port Melbourne Sand</i>	<i>Holocene</i>
<i>Coode Island Silt</i>	<i>Holocene</i>
<i>Fishermens Bend Silt</i>	<i>Last Interglacial</i>
<i>Moray Street Gravels</i>	<i>Penultimate Glacial</i>

The two younger formations are dated by radio-carbon (Gill 1970), and the two older by interpretation of sealevel changes. In the bores sunk to test the foundations for the Lower Yarra Crossing (West Gate Bridge), this same stratigraphy is revealed. The section drawn from the bore logs shows the W. edge of the delta at Newport. Quaternary formations up to 46 m deep are emplaced in a valley excavated through the Lower Pleistocene basalt, and the underlying Tertiary fluvialite, marine, and marshland sediments. The two flows of Oligocene basalt shown in Fig. 6 are also present. See Aitchison and Lang 1962, Donald and Elwood 1962, Neilson and Jenkin 1967. The lowest Quaternary formation is the Moray Street Gravels (Neilson and Jenkin 1967).

In the course of the River Yarra this stratigraphy is complicated by the presence of a Lower Pleistocene basalt flow, or series of flows. The basalt is considered to be that dated in the Merri Creek as 2.2 m.y., but could be younger. The flow probably never extended beyond the valley between the two outcrops of Oligocene basalt (Fig. 5). It is underlain by alluvial clays (Fig. 4), and has been cut through by the rejuvenated Yarra River during low stands of the sea. The Yarra River flows at the interface between the basalt and the Silurian bedrock, where its course is strictly predetermined. Beyond this limit of the

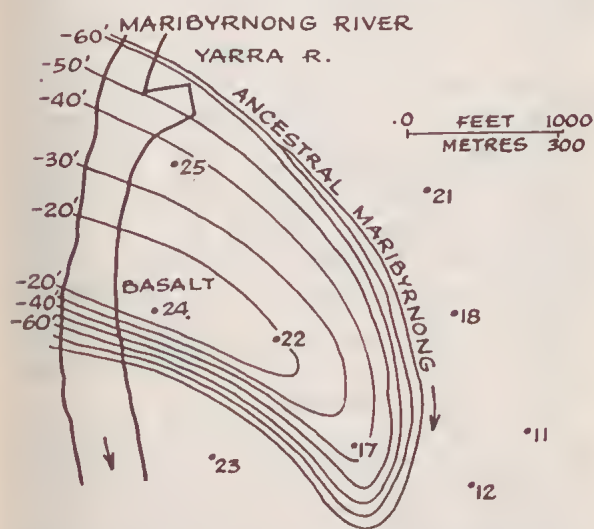


FIG. 6—Eroded basalt flow at Coode Island, Melbourne, buried in the Quaternary sediments of the Yarra Delta, and revealed by Melbourne Harbor Trust bores. Compare Figs. 7-8.

flow, however, the river has run in numerous channels across the 7 km wide fan of soft deltaic sediments. The present outlet of the river is hard against the edge of the Pleistocene lava field that defines the W. side of the delta. The shape of the course and its position are determined by the basalt. Thus the Oligocene and Pleistocene basalts have provided limits for delta formation, and river course positions.

The products of sealevel changes existing in the Yarra delta have profoundly affected certain aspects of the development of the city of Melbourne. To appreciate this, we need to look at the delta in its original condition. It was covered with vegetation, chiefly tea-tree (Bunce 1857). N. of the Yarra River and E. of the Maribyrnong River was a large shallow lake called 'Salt Lake' on Russell's original map of Melbourne, but later 'Batman's Swamp' (Selwyn 1868) and 'West Melbourne Swamp'. There were two 'lagoons', one in the area of the present Albert Park Lake, and the other at Port Melbourne where it obviously constituted the remnant of an old river channel. The first boats to sail up the Yarra had difficulty negotiating the sand bar at the mouth and the snags in the stream. They were forced to stop at the level of Market Street because there the Pleistocene basalt formed a bar across the river, making a waterfall about 1 m high. The pool below the bar was Melbourne's first port, but later landings were commonly made on Liardet's Beach (Port Melbourne), whence people walked two miles to the Yarra River which they crossed on a ferry. In time of flood, the Yarra waters flowed in a broad sheet across the flats to Port Melbourne in the vicinity of the lagoon. Further west there were sand ridges, and that is why Port Melbourne was at first called Sandridge. Similar sand ridges existed at Williamstown. The first bad flood occurred in October 1844. A particularly bad flood in December 1863 poured across South Melbourne to Port Melbourne for several days without inter-

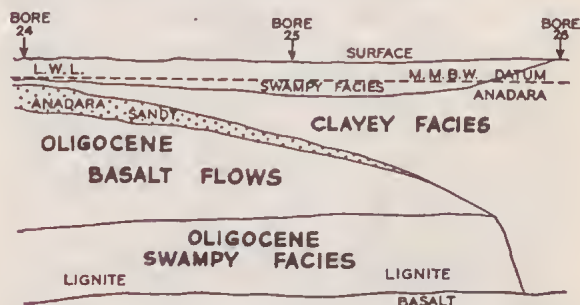


FIG. 7—Section at Coode Island, Melbourne, showing two Tertiary basalt flows covered by Flandrian sediments. Compare Figs. 6, 8.



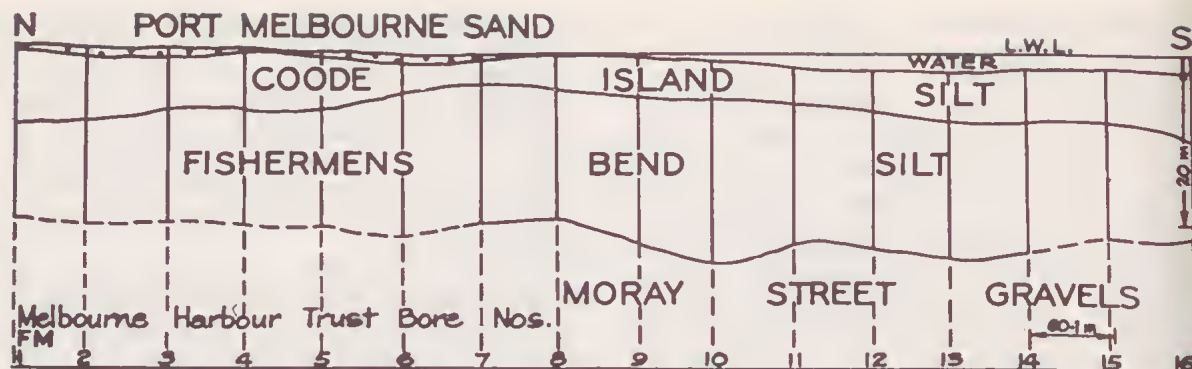


FIG. 8—Section based on cores from Melbourne Harbour Trust bores at Coode Island, Melbourne, examined by the author. Compare Figs. 6-7.

ruption (Adams 1865, Rawlinson 1865, Smith 1865, 1874). Flood control was decided upon, and in due time the river was straightened and deepened and the basalt bar across the Yarra removed.

As far as I can discover, the lagoon at Port Melbourne was used as a shelter for boats at first. Later a jetty was built in Hobson Bay just W. of the lagoon, and later a second one was built. This installation was gradually elaborated into the present Port Melbourne, but there have been difficulties as a result of sealevel changes. As heavier harbour installations were built, better foundations were necessary, but they could not be found at reasonable depth, because the port is built over an old course of the Yarra which, during a low level of the sea, cut to 30 m. The present piers are not based on this bedrock, but virtually float in the mud of this Ice Age channel. When more recently another dock was required, it was possible to choose a site with much better foundations, the River Entrance Dock. It was unfortunate that the first site chosen happened to be over a deep channel. The River Entrance Dock has a stratigraphy like that of Coode Island (Fig. 8) with some 6 m of soft unoxidized Coode Island Silt resting on compacted, oxidized Fishermens Bend Silt; the former has little bearing strength, while the latter offers a good foundation. Both formations are marine silts (as the fossils prove) laid down during an advance of the sea, but during the Last Glacial low sealevel, the Fishermens Bend Silt was drained, compacted and oxidized. Thus retreat of the sea resulted in a formation like the present marine muds of the Coode Island Silt (both contain *Anadara*) being transformed into a rock suitable for foundations. As the latter is so fine a sediment it could only be laid down more or less horizontally in conditions of low dynamics. The valleys in it were cut by subaerial erosion during the last low sealevel.

On the opposite side of Hobson Bay from Port Melbourne are Breakwater Pier and Gellibrand Pier. The distance they extended into the bay was determined by a deep channel cut during the last low sealevel and now infilled with soft silt without bearing-strength sufficient to support a pier. With ever larger oil tankers coming to Melbourne, it was necessary to extend Breakwater Pier, and the problem was solved by dredging to 18 m, then infilling with gravelly sand excavated from the bay floor off Middle Park. By courtesy of the Melbourne Harbour Trust Commissioners I saw the bores put down, and went on board the *A. D. McKenzie* during the dredging to examine the sediments brought up in the buckets (November 1953). A sample from 19 m below LWL (about the level of the Spencer St. stump and bog moss) was examined by the late Mr. N. B. Tindale, who determined the diatom flora, and found it comparable with a present-day flora from Hobart. The mollusc *Anadara trapezia* is characteristic of warmer waters further north, and is often known as the Sydney cockle. There it is common between tidemarks, but in Melbourne is at the extreme of its range, and generally is found only about LWL or below, where it is protected from the frost. This bivalve did not occur in the lower levels dredged, but was present in great numbers in the top of the section. There is thus some evidence of rising temperatures through the deposits of this channel, which is what one would expect on the glacio-custatic principle but not if the structure were due simply to faulting.

The foregoing sites may now be compared with that at the new Art Gallery site in St. Kilda Road, S. Melbourne. Fig. 9 shows a section, and Fig. 10 the contours of the Silurian bedrock. By the courtesy of Sir Roy Grounds and Milton Johnson & Associates I was provided with bore logs and given access to the bore samples. It is observed that:

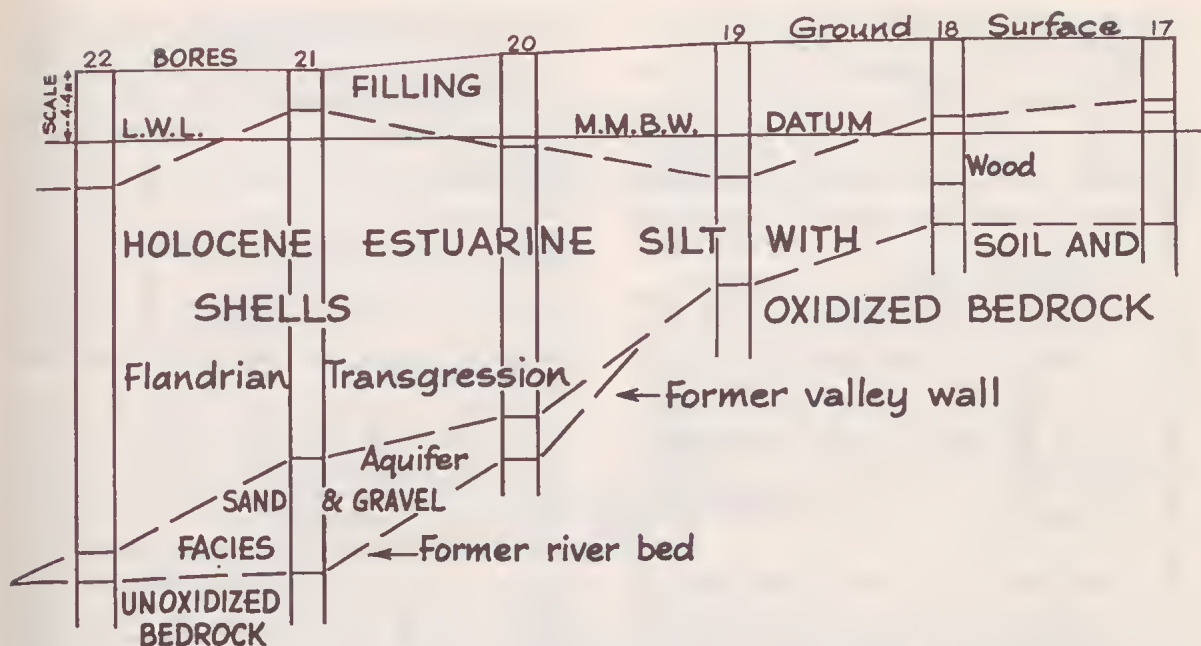


FIG. 9—Section through Art Gallery site, Melbourne (near SW. corner of Princes Bridge), showing a Last Glacial valley cut far below present sealevel, and infilled with Flandrian sediments.

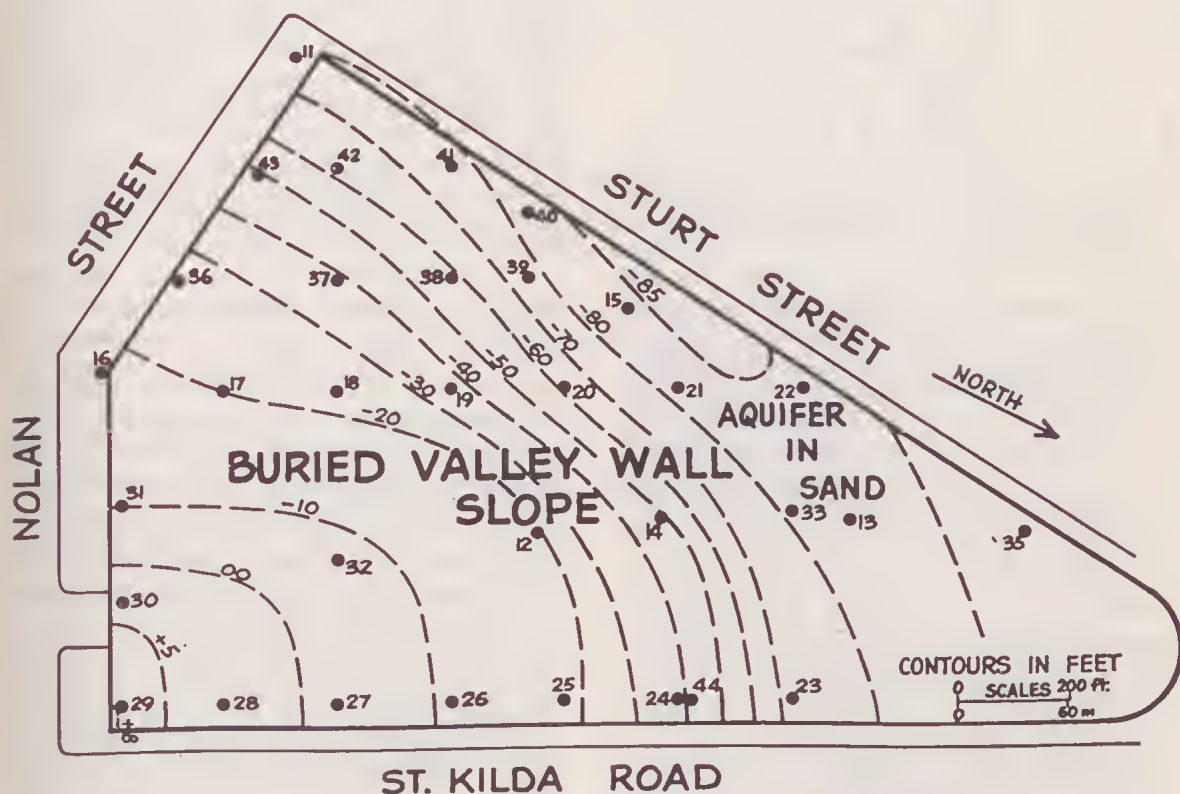


FIG. 10—Subsurface contours of the Silurian bedrock at the Art Gallery site, Melbourne, showing the E. wall of a Last Glacial Period valley, based on draft by Milton, Johnson & Associates.



(a) A channel 30 m from the surface and 25 m below LWL has been cut by the River Yarra.

(b) Wood was encountered in Bore 23 at 32 m from the surface in the Silurian bedrock, so presumably this consists of roots. I collected eucalypt roots under basalt in the floor of the Brooklyn deep sewer shaft over 30 m from the surface. Both occurrences indicate the presence of trees growing in the floor of the valley, which means that freshwater conditions prevailed.

(c) The Silurian bedrock is unoxidized below 25 m. Above this level the rock is oxidized wherever penetrated by bores. At the period when the bores were sunk, water stood near the present surface, so conditions must have been very different when air reached these rocks to oxidize them. It probably occurred during the low sealevel(s). The yellow clay with pieces of rock just above the Silurian is interpreted as a fossil soil with hillside talus.

(d) The buried valley has a steep SE. wall. This is true of the left bank of the present Yarra River as far as Merri Creek where the basalt begins. Because the basalt filled the old valley, the new Yarra River cut down steeply at the interface between the basalt and the bedrock (Fig. 5), forming cliffs in the latter as at Studley Park, E. of Melbourne city. During low sealevel(s) the river cut down further at the basalt/Silurian junction and so formed this steep valley wall.

(e) Changing ecology is indicated by the changing facies of the sediments that infill this old channel. At the base there is a gravel facies in the floor of the valley, followed by a sandy facies 4.5-6 m thick. This is an aquifer, and contained natural gas under pressure. Above is the main formation in the silt facies, a marine bed laid down as the sea returned from the Last Glacial low. Marine shells have been found in the bores and in excavations, proving that the sea deposited this formation. The three formations grade into one another, and constitute a single depositional series, but there is an obvious change in dynamics. When sealevel was low, the river flowed freely carrying gravel and sand. As the sea encroached again, a stillwater facies developed, and silts were laid in place of sands.

(f) Rocks that are absent are quite as significant as those that are present. Firstly, no Last Interglacial yellow compacted silt (Fishermens Bend Silt) is present, so either this formation was never present, or (more likely) has been eroded away. It would have been welcome to provide a foundation nearer the surface. Secondly, no basalt flow (also a good foundation) is present. Basalt was reported in the vicinity of sealevel in bores 24 and 25, but probably only boulders are there

because of the small thickness penetrated (0.3 m), the fact that bore 44 alongside bore 24 found none, and the general distribution of this rock.

(g) When the course of the ancestral River Yarra was filled by lava, the river re-established itself on the left bank at the edge of the basalt. During low sealevels a channel was excavated far below present sealevel along this edge, so that (Gill 1949) at Punt Rd. the bedrock is 18 m below sealevel, at Swan St. 19 m, at Russell St. 21 m, and at the Art Gallery site 25 m. So the Art Gallery site is in sequence, and probably represents a loop of the Yarra River formed during low sealevel.

(h) The Yarra River cut down to 25 m at the Art Gallery site (Last Glacial), and to 46 m on the W. side of the delta as is shown by the Lower Yarra Crossing bores (Penultimate Glacial). During the Last Interglacial, when sealevel was of the order of 7.5 m higher than now, marine beds were deposited and also river terraces in the coastal valleys were graded to this level. Dunes were stranded as the sea retreated. Queenscliff stands on part of such a dune line, and the Nepean Bay Bar (Kebble 1946) across the mouth of Port Phillip Bay is the remnant of another. Since then sedimentation has occurred in Port Phillip, infilling the old channels. The lowering of sealevel by 46 m would join Flinders Is. on to Tasmania (Jennings 1959), and unite the islands of the Kent Group, and of the Hogan Group, between there and Victoria. A lowering of 64 m would provide a good land bridge between Victorian and Tasmania. Across such a land bridge the Tasmanian Aborigines no doubt crossed from the mainland to the island on which they were discovered.

(i) The chronology of the recent delta fill is provided by radiocarbon datings (Gill 1971). A sample of red gum from 28.4-28.7 m in Bore 10 of the King Street Bridge series (Duigan and Cookson 1957) gave a date 12,810 y. BP., while a similar sample from 19 m in Bore 23 of the Art Gallery series gave a date of 9,650 y. BP. The peat moss at Spencer St. bridge at about 19 m dated 8,330 y., while drift wood (accompanied by estuarine shells) at Power St., South Melbourne, not far from the Art Gallery, dated 6,010 y. BP. The youngest marine bed in the delta so far dated was that on the left bank of the Maribyrnong R. at the end of Brunel St., Essendon, viz. 4,820 y. (wood bored by marine borers and in a stratified bed of estuarine shells). This layer was 0.7 m above LWL, Hobson Bay. Similar shellbeds reach up the Yarra at least as far as the Church St. bridge. These figures suggest a mean depositional rate of 1 m per 290 y. (1 cm per 2.9 y.).

These observations on the geology of the Yarra



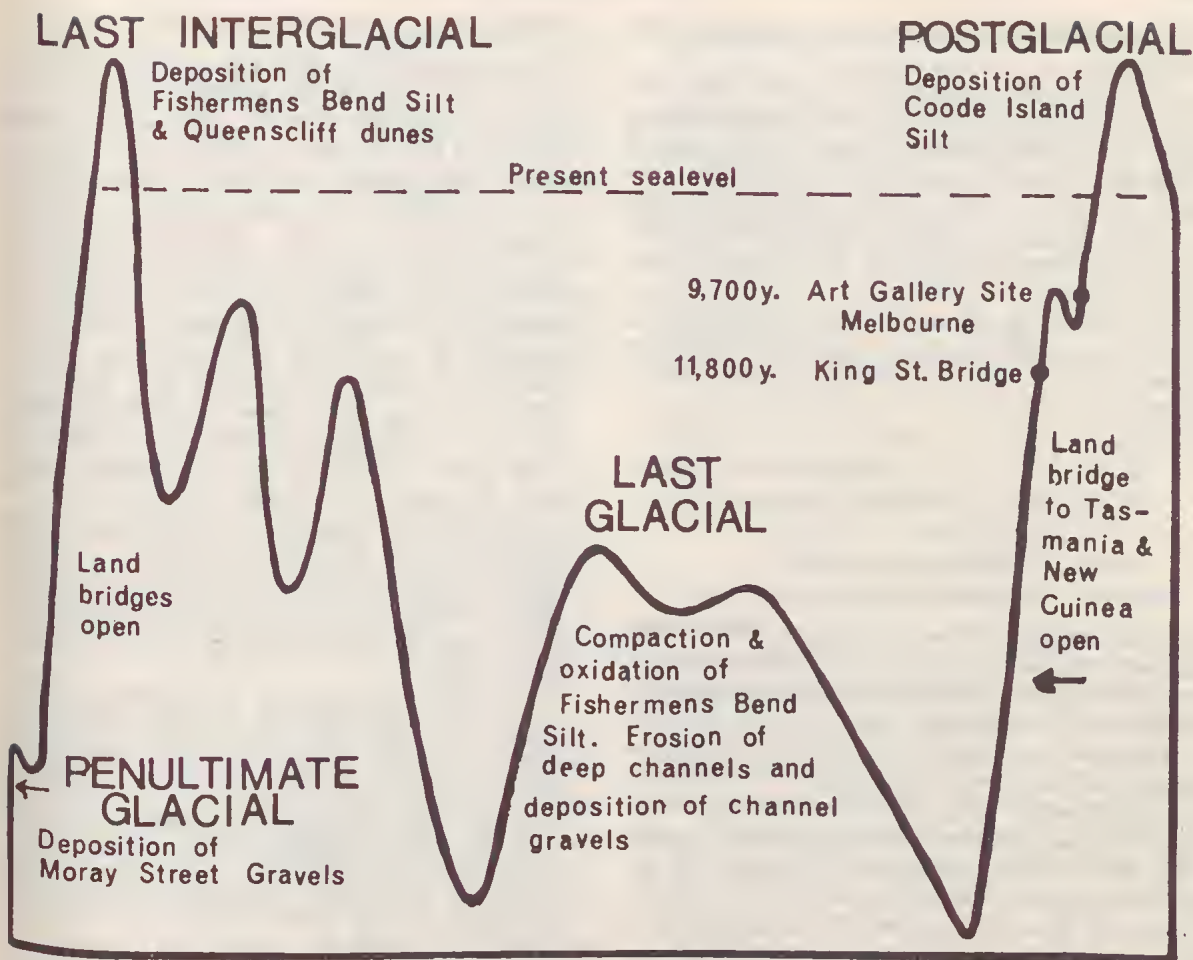


FIG. 11—Emiliani's palaeotemperature curve, which approximates the sealevel curve, because the latter is glacio-eustatic. Added are the geological formations of the Yarra Delta, Melbourne, showing their relationships to sealevel changes.

delta in relation to sealevel changes are summarized in Fig. 11.

### EUSTASY AND TECTONICS

In 1948 ANZAAS set up a Quaternary Shorelines Committee to co-ordinate by discussion and report the research in Australia and New Zealand on sealevel changes, and to link this research with overseas efforts. At that time, there was a tendency to place tectonics and eustasy in apposition. Increased knowledge and a more quantitative approach has made it clear that (1) eustasy is a global phenomenon, affecting all coasts, and (2) no coast is completely stable, but there is an enormous range in the degree of stability. The best approach is to ask, if for a given period of time, the coast being studied has been stable within a named accuracy of measurement.

The evidence advanced earlier concerning the Yarra delta proves changed relationships between

land and sea. If these changes were a function of tectonics alone, then in the past 30,000 years or so, the area has been lifted about 30 m to produce excavation of the channels, then dropped about 33 m to produce the postglacial flooding of the delta, and then raised 3 m in the last few thousand years to produce the emergence of the top of the Coode Island Silt. This is untenable because:

1. The rate of movement is out of character with the mild tectonics of the area. A tectonic environment like that in New Guinea would be needed.

2. The sudden reversals of direction in such brief time defy adequate explanation in an area of mild tectonics.

3. The low sealevels synchronize with the advance of the ice caps, while the high sealevels synchronize with their melting, thus favouring a glacio-eustatic explanation.

4. The curve of sealevel change is closely com-

parable with that observed widely throughout the world.

However, this does not mean that there has been no change in the level of the thick sediments since they were deposited. Compaction has caused lowering of levels. Also because the Yarra delta is in a sunkland setting, there probably has been a slight downward flexure, although this so far has defied measurement for the period of earth history involved.

At Altona on the west shore of Port Phillip bores and shafts sunk in connection with the winning of brown coal proved (e.g. 1928 No. 1 bore):

*metres*

- 0 - 53 *Late Cainozoic basalt*
- 53 - 87 *Upper Cainozoic non-marine clayey sands*
- 87-108 *Miocene marine marl*
- 108-145 *Oligocene brown coal and clay.*

The surface at Bore 1 is about 15 m above present sealevel. Gradual sinking caused the accumulation of the thick brown coal and associated sediments. Continuation of this sinking admitted the Miocene sea. Sinking in Port Phillip has continued so that a considerable thickness of Pliocene and Pleistocene rocks occurs in the zone of maximum sinking. Altona is on a hinge area and so has not suffered maximum movement. If the commencement of the Oligocene ( $4 \times 10^7$  y) is taken as the beginning of accumulation, and if sealevel is taken as constant, then the land has sunk of the order of 130 m in 40,000,000 years, which is 1 cm in 3,077 y. If, because of the variables involved, we doubled or even trebled this figure, the movement is still very slow, and not significant for late Quaternary stratigraphy.

At Altona (Fig. 2) there are emerged Holocene shellbeds overlying the basalt where it is near sealevel. Hills (1940) has described this coquina as rising to 1.1 m above HWM. The tidal range is about 0.9 m (Bradley 1949). The shellbeds thus occur to 2 m above LWM. As these beds are of the order of 3 m thick where studied, the compaction factor is small. Any compaction that has occurred would mean that the sediments were deposited to that much higher above sealevel. Because of the nature of the stratification, this shellbed was deposited below low water mark, and if its position to 2 m above LWL is due to tectonic movement, then (a) the movement has been in the opposite direction from that inferred from stratigraphic evidence, and (b) the rate of movement is some 70 times faster than the mean rate calculated from the stratigraphy.

## SEALEVELS AND ECOLOGY

The Altona shellbed has been explained (e.g. Jutson 1931) as due to high tides and storms, but this is unacceptable, for the shells are not broken and mixed up with other debris but are commonly whole, and quite often with both valves together in well stratified beds. The ecology is stillwater marine. Pritchard (1909) considered the formation was due to aggradation—forming a barrier then filling in behind it. This is similarly unacceptable on ecological grounds. Another explanation is that these beds represent former submarine banks (Hills 1940), but the fauna includes swamp, spray zone and intertidal shells; both sand and rock facies are represented. Such could easily accumulate in an area of shallow water deposition, but could not be lifted on to banks (if they existed) in a stillwater marine environment. In any case, such banks would be destroyed when passing through the surf zone unless elevation occurred in one climactic event, which could be out of character with the tectonics of the area.

The general structure of the Holocene beds at Altona is a stillwater marine stratum covered by a series of sandy beach ridges—an arrangement frequently found on the coasts of SE. Australia; it would seem that depressed ridges have been taken for submarine banks. In a culvert excavation on Miller Road, Altona, at the outlet to Lake Seaholme, the following section has been noted (Gill 1962, 1964):

THICKNESS	SEDIMENT	FACIES
<i>metres</i>		
0.0-0.6	<i>Black carbonaceous muddy sand</i>	<i>Marshland</i>
0.6-1.2	<i>Fawn sand (mottled with iron stains)</i>	<i>Beach</i>
1.2-1.6	<i>Fawn-grey coquina; paired whitish valves of mollusca not uncommon; top of bed sandy with mud content increasing to base</i>	<i>Stillwater Marine</i>
1.6-2.0	<i>Black sticky mud with marine fossils including paired valves of Anadara trapezia</i>	<i>Muddy inlet</i>
2.0-2.5+	<i>Bluish mud, firm but not sticky as bed above</i>	<i>Marshland</i>

Shells of *Katelysia rhytiphora* from the coquina gave a radiocarbon date of  $5,560 \pm 80$  y. (NZ), while wood from a lower level dated 7,040 y. (GaK-1061). These beds grade into one another and form a sedimentary series without strati-



graphic breaks. They define an advance, then retreat, of the sea, viz. marshland (as now), marine mud grading into marine sand (a rise in dynamics), then a stranded sandy beach and so back to the present marshland. The emergence is of the same amount and same time as found in numerous places along the coast of Victoria (Gill and Hopley 1971).

Further ecological information could be obtained by granulometric assay of the sediments, by chemical assay and by a faunal and floral assay covering the marine organisms, the spores and pollens, and the diatoms (which are good ecological indicators).

### EUSTASY AND CYCLES OF SEDIMENTATION

The Altona site shows a cycle of marine advance beginning over 7,000 y. ago followed by a marine recession less than 5,500 y. ago. Another site providing evidence of postglacial changing relationships of land and sea is that at Seaspray on the Ninety Mile Beach, E. Victoria. The site was chosen because of (1) an extensive occurrence of emerged shellbeds, (2) the ecological contrast between a high energy open ocean beach and a still water facies behind the shoreline sand barrier, and (3) the extended section from the present shore to the postglacial cliff 1.6 km inland. A series of eight bores was planned to explore this section, the first being through the beach, the second through the barrier, and the rest at intervals through the alluvial flats between the barrier and the fossil cliff. Through the helpful co-operation of Dr. G. D. Aitchison, Chief, CSIRO Division of Applied Geomechanics, some of these projected bores (2, 4, 6, 8) were carefully sunk, undisturbed cores being taken (Gill 1970).

The village of Seaspray is on Merrimans Creek, S. of Sale. A large lagoon has been formed by a coastal barrier interfering with drainage to the sea. Behind this barrier are extensive flats extending for many miles parallel to the coast. On the inland edge of the flats is a former sea cliff. To overcome the drainage problems of these flats a large drain was cut from Merrimans Creek at Seaspray 3.2 km to Lake Reeve, a part of the Gippsland Lakes complex. This excavation revealed rich shellbeds extending over the whole distance. The facies is stillwater marine and there are variations from sandy mud to muddy sand. An auger hole was put down 664 m E. of the road on the E. side of Seaspray which proved the following stratigraphy:

metres	
0.0-0.6	Black peaty soil
0.6-0.7	Grey sand
0.7-1.8+	Shell bed.

A survey was made from this point to the beach, as shown in Fig. 12. It is difficult to measure sea-level on an open ocean beach, but from the above survey it was determined that the top of the coquina is of the order of 2.1 m above LWL. A temporary gauge will give a more reliable measurement. The tidal range along the Ninety Mile Beach is of the order of 2.4 m. *Anadara trapezia* shells were collected from muddy sediment at the top of the shellbed. Both valves were in place, and the shells appeared to be in position of life. Radiocarbon date for these shells was  $4,510 \pm 80$  y. (Gill 1971).

Excavations immediately behind the barrier showed that the upper shellbed extends to near the dune without change. Bore 2 shows that the lower shellbed passes below the barrier. Apparatus for boring beach sands was not available at the

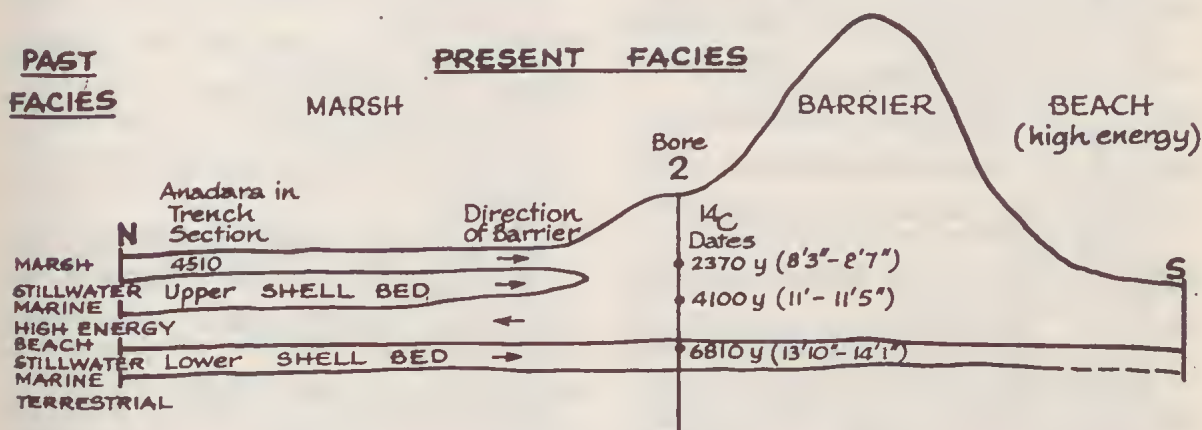


FIG. 12—Diagrammatic section through the shore and adjacent swampland N.E. of Seaspray, Gippsland, E. Victoria.



time of the field work to determine whether the shellbed passes under the beach, but fossil shells washed up on the beach support this interpretation. The barrier must have migrated over the shellbed as changes in sealevel shifted the shoreline. Since the Seaspray shellbeds are of stillwater marine facies, although beside an open ocean, there must have been a protecting barrier when they were laid down. As the shellbeds extend out towards the sea under the present barrier, it must once have been further seaward than at present.

## EUSTASY AND THE FUTURE

Sealevel has been at a comparative stillstand over the past 6,000 y., which covers the time during which mensuration was evolved and used. During the Flandrian Transgression (c. 18,000-6,000 y. BP) the sea rose about 186 m in 12,000 y., a mean rate of 1.5 m per century. If such rapid change of sealevel began now, and the move were upwards, then within a century most wharves would be of limited use, some coastal towns would be drowned, the size of the Netherlands would be considerably reduced, and Venice would be lost. The mobility of sealevel in the past should lead us to expect that the present stillstand will not last a great deal longer. If, however, the next rapid sealevel movement is downward, then the problems of Venice, the Netherlands, and coastal preservation in general will be solved, but many wharf installations will be outmoded and many coastal holiday resorts lost. Modern man has not lived in a period of rapid sealevel change, and I believe that we should give more thought to this inevitable future event.

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## THE EQUIVOCAL EXTENT OF GLACIATION IN THE SOUTHEASTERN UPLANDS OF AUSTRALIA

By J. A. PETERSON\*

### INTRODUCTION

Readers of the literature on Pleistocene glaciation of the Southeastern Uplands of mainland Australia will have noted that two opposing schools of thought have emerged. The first suggestions that glaciation has occurred in Tasmania (Gould 1860) and the Southeastern Uplands of Australia (Clarke 1860) were followed before the end of last century by vigorous dispute over 'glacial evidences' in both areas (for instance, Montgomery 1894 versus Johnston 1888, and Curran 1898 versus Helms 1894). Disagreement about the origin of certain features of the South-eastern Uplands has remained to the present time.

### ALTERNATIVE INTERPRETATIONS

Dispute centres around the identification, distribution and significance of ice abraded surfaces, certain surficial materials, and 'cirques'.

#### (a) *Smooth bedrock surfaces*

(i) Browne and Vallance (1957) describe granitic outcrops as far north as Jagungal in the Snowy Mountains as ice abraded because they are smoothly rounded in form. While these authors admit that evidence such as the rounding of hills is 'amenable to interpretation according to the taste and fancy of the observer' (Browne and Vallance 1957, p. 126), Galloway (1963) points out that granitic outcrops are characteristically rounded whether stripped of regolith by either glacial or non-glacial processes. Many of these 'roches moutonnées' are located near tors that could not have survived the passage of ice (see Galloway 1963, p. 182).

(ii) Massive outcrops of granite bedrock at the head of Dicksons Falls Creek, Buffalo Plateau, Victoria, have been attributed by Costin (1957) to glacial activity because of their association with stepped profiles and 'moraine'. Talent (1955) considers that the stepped profiles are related to major jointing in the granite, that the 'moraine'

shows retention of primary joint directions indicating that they developed *in situ*, and that glaciation need not be invoked to account for any landforms in the Buffalo area.

#### (b) *Surficial deposits*

(i) Galloway (1963) has argued for a non-glacial origin for the general spread of a regolith rich in rubble and boulders, as well as the moraine-like deposits at Island Bend and the 'David Moraine', all in the Kosciusko area.

(ii) Carr and Costin (1955) regard particular surficial materials in the Bogong High Plains area as glacial deposits whereas some or all of these are regarded by others as non-glacial, e.g. 'a residual soil developed *in situ* on granodiorite' (Beavis 1959, p. 192).

(iii) Contrary to earlier workers, Talent (1965) established that rock rivers of the uplands of Eastern Victoria are cryogenic rather than glacial.

#### (c) *Cirque-like features*

(i) Cirques in the lee of the Kosciusko-Twynam ridge form indisputable evidence for glaciation (Dulhunty 1946, Galloway 1963, p. 186, Moye and others 1969). Almost all cirques mapped elsewhere in the Snowy Mountains (e.g. Browne 1952) have however been regarded by other workers as either valley heads modified by solifluction or nivation hollows in various stages of development (see Ritchie and Jennings 1955, Galloway 1963).

(ii) In the uplands of Victoria, landforms described by Carr and Costin (1955) and Costin (1957) as cirques or cirque-like (by implication glacial) have been shown by Talent (1965) to be similar to features far below the elevations where former Pleistocene glaciation might be postulated.

(iii) Accounts urging a glacial interpretation of features over large areas of the Southeastern Uplands usually referred to 'cirque-like hollows', 'cirquoid features', and 'cirque-like ex-

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DISTRIBUTION OF CIRQUES IN THE SOUTH EASTERN UPLANDS

SHADED PORTION OF MAP INCLUDES AREAS OF OCCURRENCE  
OF CIRQUE-LIKE FEATURES OF DISPUTED ORIGIN

INSET MAP SHOWS CIRQUES OF UNDISPUTED ORIGIN



FIG. 1.—Distribution of cirque-like features in the Southeastern Uplands according to various authors (e.g. Browne 1952, Ritchie 1952, Carr and Costin 1955, Costin 1957, Galloway 1963). Landforms other than cirque-like features, and with proposed similarities to certain glacial landforms may also be found within the shaded portion of the map.



pansions' (Browne and Vallance 1957, pp. 134, 136), 'cirquated' ridge crests (Ritchie 1952, p. 92), 'cirque-like heads' (Carr and Costin 1955, p. 223) and 'weakly cirque-shaped' features (Costin 1957, p. 236) rather than to cirques. Despite Browne's (1952, p. 33) protestation that 'cirque-heads are almost universal' a cirque-like appearance does not necessarily indicate former glaciation. Indeed it is only after finding such features as over-deepening, striae, and moraine ridges that a cirque-like feature can be regarded with confidence as a glacial cirque.

A result of such conflicting interpretation is that there is a school of thought which supports the proposition that extensive glaciation was part of a pattern of multiple glaciation of the South-eastern Uplands during the Pleistocene (e.g. David 1950, Browne 1952, 1957, 1967, Browne and Vallance 1957, 1963, 1970, Carr and Costin 1955, Costin 1957, Moye and others 1969). Proponents of the other school of thought (e.g. Hills 1940, Ritchie and Jennings 1955, Beavis 1959, Galloway 1963, 1965, Galloway and Erikson 1970, and Talent 1965) maintain a much more conservative view of Pleistocene ice extent (Fig. 1), as well as of evidence advanced in support of multiple glaciation (see Derbyshire and Peterson 1971). Opinions concerning the nature and chronology of multiple glaciation in the Kosciusko area have varied from time to time (cf. Browne 1945, 1952, 1963, and Moye and others 1969).

## DISPUTED PLEISTOCENE ICE EXTENT

It can be seen from Fig. 1 that the extent of the Pleistocene ice over the Southeastern Uplands is in dispute, either directly or by implication. Browne (1952, 1957) considered that 1,000 km<sup>2</sup> (400 sq. mls) were glaciated in the Kosciusko region whereas Galloway (1963) has argued that the possible maximum extent of ice was 50 km<sup>2</sup>. Hills (1940) and Beavis (1959) did not regard the Victorian Uplands as having been glaciated, whereas Costin (1957, p. 237) considered 'an estimated area of at least 500 square miles probably . . . (have) . . . been affected'.

More recently further disagreement regarding Pleistocene ice extents has become apparent. Moye and others (1969, p. 569) succinctly summarizing the work of Browne (1952) and some others with similar views state that 'the Kosciusko Plateau is the only region on the mainland of Australia with extensive traces of Pleistocene glaciation'. On the other hand Carr and Costin (1959, p. 193) state: 'Physiographic features of a kind accepted as evidence of former glaciation in the Kosciusko region (David 1950) are also to be found in the Victorian Alps and should be

accepted by implication as evidence of glaciation in Victoria'. Clearly, the advocates of extensive glaciation in southeastern Australia are in opposition among themselves over the interpretation of the same kinds of landforms.

## A GLACIO-CLIMATIC CONSIDERATION

Further field work may resolve the arguments between the two schools of thought. It will be argued here that future syntheses should consider not only geomorphological evidence but also glacio-climatic implications.

A thick ice sheet is envisaged by Moye and others (1969) for the earliest glaciation in the Kosciusko area. Thick ice caps are nourished by net ice accumulation despite an almost complete lack of protection of their surfaces from solar radiation and wind. The accumulation area of an ice cap is therefore above the climatic snow-line. Given a measure of protection from ablation and deflation, snow will accumulate to nourish cirque glaciers, the lower boundaries of ice accumulation (firn lines) of which will lie below the climatic snow-line, and mark the local level of the orographic snow-line.

If a thick ice cap formed over the Kosciusko Plateau during Pleistocene glacial times, would not cirques have been formed on those nearby mountains which were slightly lower than the postulated area of sheet ice accumulation? Perhaps postulation of summit ice domes rather than thick ice sheets constitutes a more realistic reconstruction of Pleistocene glacial conditions. Even so, Manley (1955) has shown that modern summit ice domes of temperate latitudes only exist above the level of the lowest boundary of ice accumulation in immediately adjacent cirques, and that the narrower the summit the higher it must be above this level to support an ice dome (Fig. 2). Cirques, the floors of which approximate to the level of the former firn lines (Flint 1947) should be found at lower levels than that of postulated ice dome glaciation.

However, to date, cirques have not been mapped in areas outside the postulated limits of ice sheet occurrence. Apart from the undisputed glacial cirques in the lee of the Kosciusko-Twynnam ridge (see Galloway 1963, p. 186) no glacial cirques have been positively identified, although one feature on Mt. Howitt deserves further consideration. It was regarded as a glacial cirque by Costin (1957). Striations on a 'glacial pavement' on the headwall seemed to support strongly a glacial origin. When the writer examined this feature in December 1968 it was occupied by a snow-patch which was melting and had recently exposed the slopes immediately above the top of the headwall.



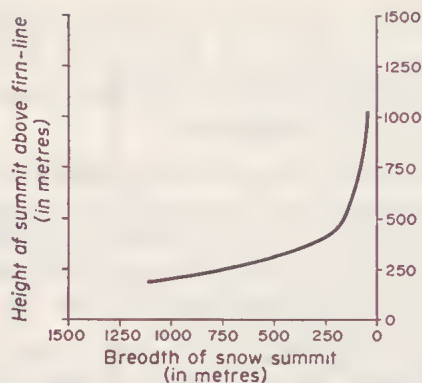


FIG. 2—Manley's Curve showing that the lower limit of ice nourishment in unselective snow accumulation areas is much higher than the lower limit for definite ice accumulation in the lee of nearby ridges—the vertical difference being greater on narrow summits (from Manley 1955, p. 455).

Those slopes bore fresh striations. These were more remarkable for the layer of powdered rock derived from the abrading stones than for the depth of marking. They were therefore thought to have been caused by mass movement of snow the previous winter after the manner described by Costin (and others 1964). The abrasion of the headwalls is not very marked under present conditions: vegetation is little disturbed at the base of the snow-patch and thrives over the floor of the feature which would, therefore, appear to be a relict of a former geomorphic environment. The feature is small; too small to be apparent on the map of the area (State Aerial Survey Victoria, Howitt Sheet 1:63360, form-line interval 100 ft). Further detailed work would be necessary to establish firmly whether it was initiated in glacial or post-glacial times. However, because it is such a small feature and there is no unequivocal evidence for glaciation, it is probably best regarded as a nivation cirque or snow-patch hollow.

## SUMMARY

Two schools of thought have emerged upon the question of Pleistocene ice extent in the South-eastern Uplands of mainland Australia and any interpretations of upland geomorphology must acknowledge the two points of view. Future interpretations should also test hypotheses in the light of their glacio-climatic implications. In this context ice-cap glaciation in the Southeastern Uplands implies that cirques would have been formed at levels lower than the lower boundary of sheet-ice accumulation. The absence of such cirques in areas adjacent to those of proposed ice-cap glaciation does not favour the ice-cap hypotheses. Preference may therefore be argued

for conclusions derived from the contentions of Hills (1940), Beavis (1959), Galloway (1963, 1965) and Talent (1965) suggesting that much of the 'glacial' evidence is more readily explained in terms of periglacial processes and that ice extent was no more than 50 km<sup>2</sup> (20 sq. mls, Galloway 1963) accumulated in cirques of undisputed glacial origin in the Kosciusko area. Periglacial processes with total estimated extent in the South-eastern Uplands of some 2,330 km<sup>2</sup> (900 sq. mls) have received scant attention from advocates of ice-cap glaciation. The more conservative estimates of ice extent imply that a considerable area of the Southeastern Uplands has suffered a period (or periods?) during which a periglacial climate largely determined the rate and form of slope wasting and weathering. Perhaps attention should now be turned to testing this implication in view of the persistence of disagreement over the 'glacial' evidences.

## ACKNOWLEDGMENTS

The writer is grateful for the helpful comments of the referees for this paper and to the Research Secretary of the Society for passing them on. Work upon which it is based was supported by the Department of Geography, Monash University, and is part of an on-going study initiated with an A.R.G.C. grant made for research into glacial and periglacial geomorphology in Australia. The writer is grateful for the cartographic assistance of J. E. Missen and G. R. Swinton of the Geography Department of Monash University.

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# POTASSIUM-ARGON DATES FROM THE COBAW GRANITE, CENTRAL VICTORIA

By A. J. STEWART\*

**ABSTRACT:** Four biotite samples from the three largest intrusions of the compound Cobaw Granite have been dated by the potassium-argon method. The four dates (347, 358, 359, and 361 m.y., all  $\pm 7$  m.y.) are all Late Devonian on the Kulp time-scale, or Early Carboniferous if the Devonian-Carboniferous boundary of McDougall *et al.* (1966) is used. The dates agree with the Devonian-Carboniferous age assigned to all the central Victorian granites on stratigraphic grounds.

## INTRODUCTION

The Cobaw Granite is situated in central Victoria, about 50 miles N. of Melbourne (Fig. 1).

It is one of several large, post-orogenic, sub-volcanic granite plutons that were emplaced into the folded and faulted Lower Palaeozoic sediments

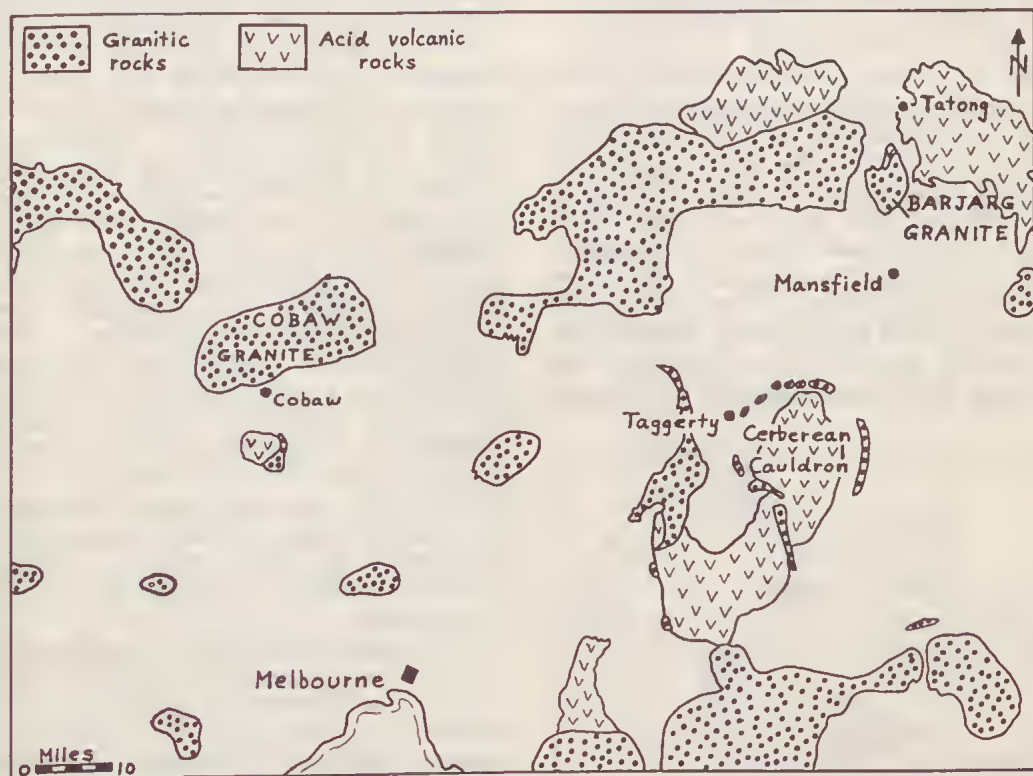


FIG. 1—Locality map of central Victoria, showing major areas of acid igneous rocks and localities referred to in text. Geological boundaries taken with slight modification from Geological Map of Victoria, 1963, 1:1,000,000, published by the Department of Mines, Melbourne, Victoria.

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of the Lachlan Geosyncline after the Tabberabberan Orogeny, which occurred in the later part of Devonian times. Some of these granites intrude acid volcanic rocks that formed an early extrusive phase of the magmatic activity (Hills 1959). On stratigraphic and palaeontologic evidence, the time of emplacement of the granite plutons is bracketed between Late Devonian and Early Carboniferous; elastic sediments interbedded with the acid volcanics of the Cerberean cauldron at Taggerty contain Late Devonian fish fossils (Hills 1931), and sediments with Early Carboniferous fish fossils (Woodward 1906) unconformably overlie granite that intrudes similar cauldron volcanics near Mansfield (Brown 1961). However, up to the present time, only one age determination on the central Victorian granites themselves has been published, viz., a Rb/Sr date of  $369 \pm 11$  m.y. (Late Devonian) on the Barjarg Granite (McDougall *et al.* 1966).

## GEOLOGICAL SETTING OF THE DATED SAMPLES

The Cobaw Granite has been described by the author in an earlier paper (Stewart 1966). The massif, shown in outline in Fig. 2, comprises a large mass of medium-grained granodiorite G3, and a wide ring of coarse-grained granite G2 that surrounds G3. A smaller mass of porphyritic granodiorite G4 interrupts the ring of granite for some 6 miles along its southern side, and has a transitional contact with G3. The earliest intrusion, G1, is an irregular dyke of hypersthene porphyrite situated outside the granite ring at its north-eastern corner. Sample 1 of the present study comes from the south-western corner of the granite ring G2, samples 2 and 3 are from two different parts of the granodiorite G3, and sample

4 is from the porphyritic granodiorite G4; the sample locations are shown in Fig. 2. All the samples were taken from fresh rock blasted loose during road construction by the local authorities. The three rock-types are described petrographically in Stewart (*op. cit.*).

## ANALYTICAL METHODS

Potassium in the samples was determined by atomic absorption spectrophotometry, and argon was extracted, purified, and its composition determined by conventional isotope dilution techniques, as set out in Armstrong (1970). The precision of the dates is 2% ( $\sigma$ ). All dates were calculated using the constants  $K\lambda\beta = 4.72 \times 10^{-10} \text{ yr}^{-1}$ ,  $K\lambda_e = 5.85 \times 10^{-11} \text{ yr}^{-1}$ ,  $K^{40}/K = 0.0119$  atom per cent. The analyses were made on mica separates obtained from the crushed and sieved whole rock, using a vibrating table and bromoform.

## RESULTS

Sample descriptions, analytical data, and K-Ar dates are set out in Table 1, and the dates are plotted in Fig. 2. Kulp (1961) placed the Devonian-Carboniferous boundary within the volcanic succession of the Cerberean cauldron, and assigned to it a date of 345 m.y., basing this in part on a biotite date of 344 m.y. from the Cerberean volcanics themselves (Evernden *et al.* 1961); this biotite date was later revised to 345 m.y. by Evernden and Richards (1962). On this basis, the four samples from the Cobaw Granite are all Late Devonian in age. McDougall *et al.* (1966) redetermined the age of the Cerberean volcanics, and concluded that the Devonian-Carboniferous boundary should be placed at  $362 \pm 6$  m.y.; using this figure, the Cobaw Granite samples are all Early Carboniferous in age. Samples 1, 3, and 4 straddle the Devonian-Carboniferous boundary of McDougall *et al.* when the  $\pm 7$  m.y. errors are taken into account. The four dates are in agreement with the Late Devonian to Early Carboniferous age assigned to the central Victorian granites from the stratigraphic and palaeontologic evidence discussed above.

With regard to the order of emplacement of the three intrusions sampled in this study, the radiometric dates add little of significance. The field evidence, summarized in Stewart (*op. cit.*), indicates clearly that the sequence of intrusion was G2, G3, and G4, in that order. The two dates on G3 (347 and 358 m.y.) are slightly younger than the 359 m.y. for G2, as they should be, but, on the other hand, the 361 m.y. determined on the youngest intrusion G4 is the oldest of the four dates found. However, the closeness of the four

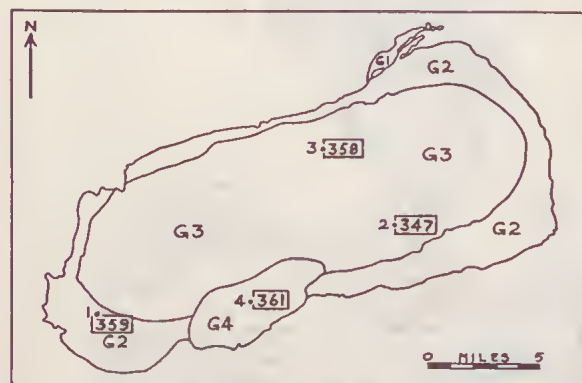


FIG. 2— Generalized geological map of Cobaw Granite, showing boundaries of major intrusions (G1 to G4), locations of dated samples 1 to 4, and the dates obtained (in m.y.; in rectangles).

dates and the resulting overlap in their errors virtually prohibits the drawing of any conclusions from the age data regarding the order of emplacement of the three intrusions. Rather, it appears that the several intrusions forming the Cobaw Granite cooled essentially as a single mass.

### ACKNOWLEDGMENTS

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TABLE 1

SAMPLE DESCRIPTIONS, ANALYTICAL DATA, AND K-Ar DATES FOR THE COBAW GRANITE

Sample No.	Lithology	Material* Dated	%K	Radiogenic Ar STP (cc/gm) $\times 10^6$ (per cent air correction in parentheses)	Date (m.y.)
1	Granite (G2)	Biotite (1% chlorite)	7.29, 7.39	115.96 (9)	359
2	Granodiorite (G3)	Biotite (2% chlorite, tr. hornblende)	6.51, 6.57	99.55 (9)	347
3	Granodiorite (G3)	Biotite (2% chlorite, tr. hornblende)	6.46, 6.51	102.14 (4)	358
4	Granodiorite (G4)	Biotite (3% chlorite, tr. hornblende)	5.51, 5.62	87.83 (5) 88.96 (5)	359 363 av. = 361

\* Chlorite percentage reported is estimated from the heights of the 14 Å and 10 Å peaks on X-ray diffraction curves; it is not an accurate measure of the actual chlorite content. Presence of hornblende indicated by X-ray diffraction curve.





# CRETACEOUS MICROPLANKTON FROM EYRE No. 1 BORE CORE 20, WESTERN AUSTRALIA

By ISABEL C. COOKSON\* and A. EISENACK†

With Introduction by B. S. INGRAM‡

**ABSTRACT:** 28 species assignable to 18 genera including one new genus *Eyrea* and eleven new species are herein recorded from the Eyre Bore No. 1 core 20, between 1,400-1,410 ft, Western Australia. A remarkable feature has been the frequency and number of species of the genus *Pterospermopsis* W. Wetzel 1952, especially *P. aureolata* Cookson and Eisenack 1958.

## INTRODUCTION

Cookson and Eisenack (1970) described assemblages of microplankton from two bores in the Eucla Basin, Western Australia. The present paper extends the work, as it describes assemblages from Exoil Pty. Ltd.'s exploration well Eyre No. 1 drilled in 1959-60 at the geographic co-ordinates—

32°07'S.  
126°58'E.

The sample comes from core 20 (1,400-1,410 ft), and is a dark grey silty mudstone. In a preliminary stratigraphic study using the spores, pollen grains and microplankton from various Cretaceous rocks of the Eucla Basin, Ingram (1968) considered this sample to be Albian-Cenomanian in age.

## SYSTEMATIC DESCRIPTIONS

The registered numbers given for Holotypes and Hypotypes are those of the Palynological Collection of the Geological Survey of Western Australia.

Division PYRRHOPHYTA Pascher 1914

Class DINOPHYCEAE Fritsch 1929

Family GONYAULACYSTACEAE Sarjeant and  
Downie 1966

Genus *Cribroperidinium* Neale and Sarjeant 1962

*Cribroperidinium edwardsi* (Cookson and Eisenack)  
Davey 1969, p. 125

(Pl. 7, fig. 1 F8065)

*Gonyaulax edwardsi* Cookson and Eisenack 1958,  
p. 32, Pl. 3, fig. 5, 6.

*Gonyaulax edwardsi* Cookson and Eisenack, Cookson and Hughes 1964, p. 43, Pl. 5, fig. 9.

*Gonyaulax edwardsi* Cookson and Eisenack 1968,  
p. 117, fig. 5A and B.

*Gonyaulax edwardsi* Cookson and Eisenack, Ingram 1968, p. 65.

*Cribroperidinium edwardsi* Cookson and Eisenack,  
Davey 1969, p. 128.

**AGE AND OCCURRENCE:** Mid-Cretaceous, Eyre Bore No. 1 core 20, Western Australia.

**DIMENSIONS:** Overall length *c.* 162-280  $\mu$ , overall breadth *c.* 138-239  $\mu$ .

**COMMENT:** Several specimens which agree in general features with *G. edwardsi* from a number of Lower and Upper Cretaceous Western Australian deposits have been present in residues of the Eyre Bore No. 1 core 20. However, taken as a whole, they are rather larger than those on which the species was based.

Family DEFLANDREACEAE Eisenack 1954

Genus *Deflandrea* Eisenack 1938

*Deflandrea eyrensis* n. sp.

(Pl. 7, fig. 2, 3, Holotype fig. 3 F8066)

**AGE AND OCCURRENCE:** Mid-Cretaceous Eyre Bore No. 1 core 20, Western Australia.

**DESCRIPTION:** Shell considerably longer than broad, resembling in that respect *D. bakeri* Deflandre and Cookson (1955) and *D. scheii* Manum (1963).

Epitheca longer than the hypotheca, dome-shaped with a very short centrally-placed apical horn. Hypotheca with convex sides which slant towards a very short antapical prominence situated towards the left-hand side of the dorsal surface. Girdle circular and

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rather broad (Pl. 7, fig. 3). Wall of shell thin, slightly to rather coarsely and densely granular especially in the upper portion of the epitheca. Capsule relatively large, roughly oval in shape but not reaching the lateral walls of the shell. Surface closely granular varying somewhat in the degrees of density. Archeopyle relatively small, when clearly developed, as in the holotype, six-sided.

**DIMENSIONS:** Holotype—shell c.  $90\ \mu \times 56\ \mu$ , capsule c.  $60\ \mu \times 60\ \mu$ . Range from shell c.  $72\ \mu \times 45\ \mu$ , capsule c.  $48\ \mu \times 42\ \mu$  to shell c.  $121\ \mu \times 82\ \mu$ , capsule c.  $80\ \mu \times 60\ \mu$ .

**COMMENT:** *D. eyrensis* has occurred frequently in preparations of the Eyre deposit core 20. As the illustrations show, a considerable degree of variation both in the density and coarseness of the ornament of the shell occurs.

***Deflandrea ingrami* Cookson and Eisenack 1970a**

(Pl. 7, fig. 4)

*Deflandrea ingrami* Cookson and Eisenack 1970a, p. 143, Pl. 12, fig. 7-9.

**DIMENSIONS:** Figured specimen c.  $84\ \mu$  long, c.  $67\ \mu$  broad. Range c.  $62-95\ \mu$  long, c.  $50-70\ \mu$  broad.

**COMMENT:** *D. ingrami*, a common constituent of the Senonian portion of the Madura No. 1 Bore, Western Australia, is also relatively frequent in the Mid-Cretaceous Eyre sample. As in the Madura examples, the surface thickenings vary in clearness and prominence and the archeopyle is six-sided.

? Genus ***Ascodinium*** Cookson and Eisenack 1960

? ***Ascodinium trendalli* Cookson and Eisenack 1970a**

(Pl. 7, fig. 5, 6 F8067)

? *Ascodinium trendalli* Cookson and Eisenack 1970a, p. 145, Pl. 12, fig. 5, 6.

**AGE AND OCCURRENCE:** Senonian, Albian-Cenomanian: Madura No. 1 Bore, Western Australia, 1,018-1,072 ft and 1,073-1,104 ft. Mid-Cretaceous, Eyre No. 1 Bore core 20, Western Australia.

**DIMENSIONS:** c.  $62-88\ \mu$  long, c.  $50-70\ \mu$  broad (16 specimens measured).

**COMMENT:** As in the many examples of this species from the Madura Bore (Cookson and Eisenack 1970a), the numerous comparable specimens from the Eyre Bore sample have shown no sign of an archeopyle. For this reason we regard the generic assignment to *Ascodinium*, adopted previously and herein, as doubtful. The Eyre specimens agree in general features with those from the Madura Bore but the walls of their capsules are distinctly thinner and the shells somewhat broader than those from the latter locality. Individual specimens have varied considerably as to the degree of ornamentation. The occurrence of the wavy thickening on the ventral surface of the hypotheca, which we believe to have been associated with the flagellum has been, as in the Madura examples and many other types (Cookson and Eisenack 1970a, p. 153), constantly present.

Family **MICRODINIACEAE** Eisenack 1964

Genus ***Microdinium*** Cookson and Eisenack 1960  
emend Sarjeant 1966, p. 148

***Microdinium ornatum* Cookson and Eisenack 1960**

(Pl. 7, fig. 7, 8, 9, fig. 7 F8068, fig. 8-9 F8069)

*Microdinium ornatum* Cookson and Eisenack 1960, p. 6, Pl. 2, fig. 3-8, text fig. 2-4.

*Microdinium ornatum* Manum and Cookson 1964, p. 19, Pl. 19, fig. 8-10.

*Microdinium cf. ornatum* Sarjeant 1966, 'Studies', p. 149, Pl. 16, fig. 3-6, text fig. 38.

*Microdinium ornatum* Clarke and Verdier 1967, p. 66, Pl. 5, fig. 11-14.

*Microdinium cf. ornatum* Davey 1969, p. 132, Pl. 4, fig. 5, text fig. 13C. F.

**AGE AND OCCURRENCE:** Mid-Cretaceous, Eyre Bore No. 1 core 20, Western Australia, and several other Albian-Cenomanian Western Australian deposits (Cookson and Eisenack 1960).

**DIMENSIONS:** Figured specimen (Pl. 7, fig. 8, 9) c.  $42\ \mu$  long, c.  $34\ \mu$  broad. Range c.  $33-54\ \mu$  long, c.  $38-48\ \mu$  broad.

**COMMENT:** Several specimens which agree well both in tabulation and ornamentation with the type specimens have been recovered from the Eyre residues. The ones illustrated are distinctly larger and the borders of the plates and their bead-like supports more prominent than those of the type specimens from Western Australian Lower and Middle Cretaceous deposits. However, there is little doubt that the Eyre specimens are closely related to *M. ornatum*. The mode of opening of the shell by the removal of the apical plate is well shown in Pl. 7, fig. 7, 8.

***Microdinium veligerum* (Deflandre) Davey 1969**

(Pl. 7, fig. 10)

*Microhystridium veligerum* Deflandre 1937, p. 81, Pl. 12, fig. 9.

*Ceratocorys veligera* (Deflandre) Lejeune-Carpentier 1943, 67: p. 22, text fig. 1-6.

*Eisenackia crassitabulata* (Deflandre) Clarke and Verdier 1967, 24: No. 3, p. 64, Pl. 8, fig. 4-6.

*Microdinium veligerum* (Deflandre) Davey 1969, p. 136, Pl. 3, fig. 4, Pl. 4, fig. 4.

**COMMENT:** Three examples referable to *M. veligerum* have been recovered from the Eyre Bore No. 1 core 20. The one illustrated Pl. 7, fig. 10 is c.  $40\ \mu$  long and c.  $38\ \mu$  broad.

***Microdinium* sp.**

(Pl. 7, fig. 11 F 8070)

**AGE AND OCCURRENCE:** Mid-Cretaceous, Eyre Bore No. 1 core 20, Western Australia.

**DIMENSIONS:** c.  $33\ \mu$  long, c.  $33\ \mu$  broad.

**COMMENT:** The genus *Microdinium* is represented by what appears to be a third species in which an ornamentation is scarcely visible. However, more examples will be needed for the specific placing of this form.



Family HYSTRICHOSPHAERACEAE O. Wetzel  
emend Evitt 1963

Genus *Hystrichosphaera* O. Wetzel 1933, restr.  
Deflandre 1937

*Hystrichosphaera ramosa* (Ehrenberg 1838) var.  
*ramosa* Davey & Williams 1966  
(Pl. 8, fig. 1, 2 F 8071, F 8072)

*Xantlium ramosum* Ehrenberg 1938, 1: pp. 109-136,  
Pl. 1, fig. 15.

*Hystrichosphaera ramosa* (Ehr.) O. Wetzel 1933,  
p. 78, Pl. 5, fig. 7, 8, 10-12, 18, 19.

*Hystrichosphaera ramosa* (Ehr.) Lejeune-Carpentier  
1937, p. 6, Pl. 5, fig. 1, 2.

*Hystrichosphaera ramosa* (Ehr.) Deflandre and Cook-  
son 1955, p. 263, Pl. 2, fig. 1, Pl. 5, fig. 6, Pl. 6, fig. 1.

*Hystrichosphaera ramosa* (Ehr.) var. *ramosa* Davey  
and Williams 1966, 3: p. 33, Pl. 1, fig. 1-6.

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore  
No. 1 core 20, Western Australia.

DIMENSIONS OF 9 SPECIMENS: Shell length c. 52-87  $\mu$ ,  
breadth c. 47-76  $\mu$ . Overall length c. 84-146  $\mu$ , overall  
breadth c. 76-133  $\mu$ , appendages c. 28  $\mu$  long.

COMMENT: Nine examples of this species have been  
mounted from the Eyre Bore No. 1 core 20 residues  
and more have been seen. All agree in shape, distribu-  
tion and form of the appendages of this species but  
are larger than those of the previously recorded  
examples.

In the shape and relative length of the appendages  
they agree best with the figures given by Lejeune-  
Carpentier 1937, Pl. 2. The appendages are definitely  
bifurcate.

Family AREOLIGERACEAE Evitt 1962

Genus *Cyclonephelium* Deflandre and Cookson 1955  
emended, Cookson and Eisenack 1962b

*Cyclonephelium membraniphorum* Cookson and  
Eisenack 1962  
(Pl. 8, fig. 3 F 8073)

*Cyclonephelium compactum* Deflandre and Cookson  
1955, p. 285; Cookson and Eisenack 1958, p. 48,  
Pl. 12, fig. 8.

*Cyclonephelium membraniphorum* Cookson and  
Eisenack 1962b, p. 495, Pl. 6, fig. 8-14.

*Cyclonephelium membraniphorum* Cookson and  
Eisenack 1968, p. 120.

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore  
No. 1 core 20, Western Australia.

COMMENT: The example figured herein is closely  
comparable with the ones shown by Cookson and  
Eisenack 1962b, Pl. 6, fig. 11, from Wapet's seismic  
shot hole B1, Western Australia, at 210 ft and in  
1968 from the Gingin Brook No. 4 Borehole core 2,  
between 404 and 414 ft, Western Australia.

*Cyclonephelium reticulosum* Gerlach 1961

(Pl. 8, fig. 4 F 8074)

*Cyclonephelium reticulosum* Gerlach 1961, Abh. 112,  
p. 204.

*Cyclonephelium reticulosum* Gerlach, Cookson and  
Eisenack 1967, p. 251, Pl. 41, fig. 5, 6.

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore  
No. 1 core 20, Western Australia.

COMMENT: *Cyclonephelium reticulosum* is represented  
by several well-preserved specimens, the apices of  
which seem to be somewhat finer than those of the  
holotype from a West German Oligocene deposit  
(Gerlach 1961).

Family CANNINGIACEAE Sarjeant and Downie  
1962b

Genus *Canningia* Cookson and Eisenack 1960  
*Canningia circularis* n. sp.

(Pl. 8, fig. 6 F 8076)

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore  
No. 1 core 20, Western Australia.

DIMENSIONS: Holotype c. 90  $\mu$  long, c. 107  $\mu$  broad.  
Range: breadth c. 83-107  $\mu$ .

DESCRIPTION: Shell flat, almost circular to slightly  
oval in outline, the longitudinal axis somewhat shorter  
than the breadth, without tabulation and prominences.  
Surface densely covered with short, broadly-based,  
pointed tubercles. The shell opens by the detachment  
of the central portion of the apex.

COMMENT: *C. circularis* occurs frequently in the Eyre  
deposit. It is close to *C. ringnessi* Manum and Cook-  
son 1964 but differs from that species in the absence  
of an apical prominence and the coarser ornamenta-  
tion of the shell.

*Cyclonephelium distinctum* Deflandre and Cookson  
1955 emended Cookson and Eisenack 1962b

(Pl. 8, fig. 5 F 8075)

*Cyclonephelium distinctum* Deflandre and Cookson  
1955, p. 285, Pl. 2, fig. 14.

*Cyclonephelium distinctum* Deflandre and Cookson,  
Gocht 1959, p. 77, Pl. 4, fig. 16-18.

*Circulodinium deflandrei* Alberti 1961, p. 29, Pl. 4,  
fig. 7-13.

*Cyclonephelium distinctum* Deflandre and Cookson,  
Cookson and Eisenack 1962b, p. 494, Pl. 5, fig. 4-11.

*Cyclonephelium distinctum* Deflandre and Cookson,  
Cookson and Eisenack 1968, p. 120, fig. 4F.

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore  
No. 1 core 20, Western Australia.

DIMENSIONS: Figured specimen overall measurement  
c. 128  $\mu \times 124 \mu$ .

COMMENT: *C. distinctum* is represented by a number  
of rather large specimens, the ornamentation of which  
has varied considerably. The appendages have been  
either rather short and only slightly broadened at the  
apex or forked or, as in the example illustrated, rather  
long and distinctly forked.

Family HYSTRICHOSPHAERIDIACEAE Evitt 1963  
emend Sarjeant and Downie 1966

Genus *Oligosphaeridium* Davey and Williams 1966  
*Oligosphaeridium pulcherrimum* (Deflandre and  
Cookson) Davey and Williams 1966

(Pl. 8, fig. 7 F8077)

*Hystrichosphaeridium pulcherrimum* Deflandre and  
Cookson 1955, p. 270, Pl. 1, fig. 8, text fig. 21, 22.

*Hystrichosphaeridium pulcherrimum* Deflandre and  
Cookson 1955, Valensi 1955, p. 593, Pl. 4, fig. 1.

*Oligosphaeridium pulcherrimum* (Deflandre and  
Cookson) Davey and Williams 1966, p. 75, Pl. 10,  
fig. 9, Pl. 11, fig. 5, p. 114, fig. 4E.

COMMENT: It is of interest that the dimensions of the  
specimens from the Eyre Bore No. 1 core 20 are  
larger than those given previously. The measurements  
of three of those examined are: (1) shell c.  $80 \times 82 \mu$ ,  
overall c.  $162 \times 162 \mu$  complete with 11 append-  
ages; (2) shell c.  $68 \times 76 \mu$ , overall c.  $162-176 \mu$   
with an archeopyle; (3) shell c.  $104 \times 94 \mu$ , overall  
c.  $171 \times 182 \mu$  complete.

Genus *Cleistosphaeridium* Davey, Downie, Sarjeant  
and Williams 1966, p. 170

Cf. *Cleistosphaeridium polytrichum* (Valensi 1947)  
(Pl. 11, fig. 10 F8102)

*Hystrichosphaeridium polytrichum* Valensi 1947, p.  
818, fig. 4.

*Hystrichosphaeridium polytrichum* Valensi 1947, De-  
flandre and Cookson 1955, p. 272, Pl. 2, fig. 2.

*Cleistosphaeridium polytrichum* (Valensi 1947) Davey,  
Downie, Sarjeant and Williams 1966, p. 170.

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore  
No. 1 core 20, Western Australia.

DIMENSIONS: Diameter of shell c.  $40 \mu$ , overall  
diameter c.  $54 \mu$ .

COMMENT: The figured specimen is the only one of  
its kind isolated from the Eyre Bore No. 1 core 20.  
It shows no sign of an archeopyle so that a definite  
assignment to *C. polytrichum* cannot be made.

Family EXOCHOSPHAERIDIACEAE Sarjeant and  
Downie 1966

? Genus *Exochosphaeridium* Davey, Downie, Sarjeant  
and Williams 1966

? *Exochosphaeridium* aff. *striolatum* (Deflandre 1937a)  
(Pl. 11, fig. 11 F8013)

*Hystrichosphaeridium striolatum* Deflandre 1937a, p.  
72, Pl. 15, fig. 1, 2.

*Exochosphaeridium striolatum* (Deflandre 1937a)  
Davey 1969, p. 165.

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore  
No. 1 core 20.

DIMENSIONS: Overall diameter c.  $46 \mu$ , central body  
c.  $35 \mu$ , spines c.  $7-10 \mu$  long.

COMMENT: The figured specimen, the only one of its  
kind recovered from the Eyre Bore sample, seems to  
have some affinity with the genus *Exochosphaeridium*

and in particular with *E. striolatum* (Deflandre)  
Davey 1969. It is of interest in that there is an indica-  
tion of an apical archeopyle.

Family MEMBRANILARNACIACEAE Eisenack 1963

Genus *Chlamydophorella* Cookson and Eisenack 1958

*Chlamydophorella nyei* Cookson and Eisenack 1958  
(Pl. 9, fig. 1 F8078)

*Chlamydophorella nyei* Cookson and Eisenack 1958,  
p. 56.

DIMENSIONS: Figured example overall length c.  $62 \mu$ ,  
overall breadth c.  $52 \mu$ .

COMMENT: The occurrence of *C. nyei* in the Eyre  
Bore core 20 under consideration is not surprising  
since this species has been recorded from a relatively  
large number of Western Australian deposits which  
range in age from Lower to Upper Cretaceous (Cook-  
son and Eisenack 1958, p. 56). The Eyre Bore speci-  
men, illustrated herein, is lying laterally and thus  
shows very clearly the apical projection of the shell  
referred to in the original description.

*Chlamydophorella* sp.

(Pl. 9, fig. 2, 3 F8079, F8080)

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore  
No. 1 core 20.

DIMENSIONS: Specimen on Pl. 9, fig. 2, overall dimen-  
sion c.  $42 \times 38 \mu$ , shell c.  $37 \times 29 \mu$ . Range, overall  
diameter c.  $30 \times 44 \mu$ , length of appendages c.  $1-5 \mu$ .

COMMENT: The examples from the Eyre Bore herein  
referred to as *Chlamydophorella* sp. seem to be close  
to the ones referred to by Deflandre and Cookson as  
*Hystrichosphaeridium fimbriatum* (White) Deflandre  
from the Lower Cretaceous deposit on Onepah Sta-  
tion, New South Wales (Deflandre and Cookson 1955,  
Pl. 2, fig. 4). However, the appendages of the Eyre  
examples appear to be shorter, more densely arranged  
and in side view to be joined terminally.

Family Incerta

? Genus *Operculodinium* Wall 1967

The following two forms are only provisionally  
referred to the genus *Operculodinium* since in them  
an archeopyle has not, as yet, been observed.

? *Operculodinium punctatum* n. sp.

(Pl. 9, fig. 6, Holotype F8082)

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore  
No. 1 core 20.

DIMENSIONS: Holotype, diameter c.  $48 \mu$ , height of  
tubercles less than  $1 \mu$ .

DESCRIPTION: Shell spherical, closely covered with  
minute tubercles the bases of which are distinctly  
circular in outline. An archeopyle has not been  
observed.

? *Operculodinium rarispinosum* n. sp.

(Pl. 9, fig. 7, 8, Holotype F8083, Paratype F8084)

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore  
No. 1 core 20.



**DIMENSIONS:** Holotype fig. 7, overall diameter c. 59  $\mu$ , diameter of shell c. 55  $\mu$ , length of spines, c. 1-1.5  $\mu$ . Range, diameter of shell c. 32-55  $\mu$ , spines c. 1-2  $\mu$  long.

**DESCRIPTION:** Shell spherical, rather thick-walled, covered with somewhat sparsely distributed short, bluntly-pointed, solid spines. An archeopyle has not been observed.

### Group ACritarcha Evitt 1963

#### Sub-group Dinetromorphitae Downie, Evitt and Sarjeant 1963

#### Family Diplostaceae Cookson and Eisenack

##### Genus *Diplofusa* Cookson and Eisenack 1960

##### *Diplofusa gearlensis* Cookson and Eisenack 1960

(Pl. 9, fig. 4)

*Diplofusa gearlensis* Cookson and Eisenack 1960, p. 10, Pl. 3, fig. 10.

**AGE AND OCCURRENCE:** Mid-Cretaceous, Eyre Bore No. 1 core 20, Western Australia.

**DIMENSIONS:** Overall length c. 142  $\mu$ , breadth c. 38  $\mu$ , inner body c. 115  $\times$  32  $\mu$ .

**COMMENT:** The figured specimen agrees in all features with the Holotype from the Cenomanian Upper Gearle Siltstone, Western Australia, Wapet's Rough Range South Bore, core 68, 2,715-2,717 ft. In addition a circular pylome of about 20  $\mu$  diameter seems to be indicated at the apical end of the shell, a feature not previously reported.

#### Sub-group Hercomorphitae Downie, Evitt and Sarjeant 1963

#### Family Cymatiosphaeraceae Maedler 1963

##### Genus *Cymatiosphaera* O. Wetzel 1933 emend Deflandre 1954

##### *Cymatiosphaera tremaphora* n. sp.

(Pl. 9, fig. 12-14, Holotype fig. 12 F8087, Paratype fig. 13 F8088)

**AGE AND OCCURRENCE:** Mid-Cretaceous, Eyre Bore No. 1 core 20.

**DIMENSIONS:** Holotype, Pl. 9, fig. 12, diameter of shell c. 48  $\mu$ , overall diameter c. 52  $\mu$ , wall c. 2-3  $\mu$ . Range of 16 specimens: Shell c. 25-52  $\mu$ , overall c. 30-57  $\mu$ .

**DESCRIPTION:** Shell relatively thick-walled provided with low clearly-defined ledges which, by their union, form numerous 4-6-sided polygonal areas the outlines of which may be slightly wavy. At the angular points where the ledges of adjacent areas join, minute unthickened areas are sometimes evident (Pl. 9, fig. 13, 14). In the specimen illustrated on Pl. 9, fig. 14, a small circularly outlined, centrally-placed raised area is indicated in three of the fields, to the left of the middle of the shell. These areas closely resemble those present in the holotype of *C. stigmata* Cookson and Eisenack 1958, Pl. 9, fig. 14.

The number of polygons in one half-sphere of

specimens of normal size is about 25. In median optical section there are about 15-20 ledges placed around the circumference.

##### *Cymatiosphaera delicata* n. sp.

(Pl. 10, fig. 12-14, Holotype fig. 13 F8097)

**AGE AND OCCURRENCE:** Mid-Cretaceous, Eyre Bore No. 1 core 20, Western Australia.

**DIMENSIONS:** Holotype (Pl. 4, fig. 13): Shell diameter c. 60  $\mu$ , overall diameter c. 67  $\mu$ , wall c. 3  $\mu$ . Range: Diameter of shell c. 52-78  $\mu$ , overall diameter c. 60-94  $\mu$ , wall c. 2-3  $\mu$ , ledges c. 4-7  $\mu$ . Six specimens measured.

**DESCRIPTION:** Shell relatively large with a thickish wall and delicate high ledges which form rather large 5- or 6-sided polygons the number of which on one half-sphere is about six or seven. No pylome has been observed.

##### *Cymatiosphaera* sp.

(Pl. 9, fig. 9-11, fig. 10 F8085, fig. 11 F8086)

**AGE AND OCCURRENCE:** Mid-Cretaceous, Eyre Bore No. 1 core 20.

**DIMENSIONS:** Fig. 11, diameter of shell c. 25  $\mu$ , overall diameter c. 30  $\mu$ . Fig. 9, 10, two views of the same specimen. Shell c. 33  $\mu$ , overall diameter c. 40  $\mu$ .

**COMMENT:** A few considerably smaller specimens with fewer ledges than those of *C. tremaphora* (Pl. 9, fig. 12-14) have been met with. For example the exposed surface of the specimen shown on Pl. 9, fig. 9, has c. 22 fields with ledges c. 2-5  $\mu$  in height, the one on Pl. 9, fig. 11, has c. 14 fields of approximately the same height. At present it is not possible to know whether or not such specimens represent young stages in the development of *C. tremaphora* or a fully developed and distinctive type.

#### Sub-group Pteromorphitae Downie, Evitt and Sarjeant 1963

#### Family Pterospermopsiaceae Eisenack 1954

##### Genus *Pterospermopsis* W. Wetzel 1952

##### *Pterospermopsis aureolata* Cookson and Eisenack 1958

(Pl. 10, fig. 1-3 F8089, F8090)

*Pterospermopsis aureolata* Cookson and Eisenack 1958, p. 49, Pl. 9, fig. 9-13.

**AGE AND OCCURRENCE:** Mid-Cretaceous, Eyre Bore No. 1 core 20, Western Australia.

**DIMENSIONS:** Overall diameter c. 57-235  $\mu$ , shell c. 32-128  $\mu$ . Overall diameter of small example (Pl. 10, fig. 3) c. 33  $\mu$ .

**COMMENT:** Specimens of this species, originally described and recorded from a relatively large number of Cretaceous deposits in Western Australia, South Australia and Queensland (Cookson and Eisenack 1958, p. 49) have been recovered from the Eyre No. 1 Bore core 20. The range in size agrees well with that given in the original description. Large or moderately large specimens of *P. aureolata* are readily recognizable, but the relationships of some smaller ones of



similar construction are more difficult to determine (Pl. 7, fig. 3). It is possible that such specimens could represent either young stages of *P. aureolata* or a distinct species. More specimens will be needed to settle this question. The wing of *P. aureolata* is two-layered, a feature best seen in broken examples.

***Pterospermopsis australiensis* Deflandre and Cookson 1955**

(Pl. 10, fig. 4-6, fig. 5 F8091, fig. 6 F8092)

*Pterospermopsis australiensis* Deflandre and Cookson 1955, p. 286, fig. 52, 53, Pl. 3, fig. 4.

*Pterospermopsis helios* Sarjeant 1959, p. 342, Pl. 13, fig. 9.

*Pterospermopsis australiensis* Deflandre and Cookson 1955, Stanley, J. A. 1965, p. 234, Pl. 23, fig. 8, 9.

AGE AND OCCURRENCE: Lower Cretaceous: Onepah Station, New South Wales. Mid-Cretaceous: Eyre Bore No. 1 core 20, Western Australia.

DIMENSIONS: Diameter of shell c. 10-26  $\mu$ , overall diameter c. 25-53  $\mu$ .

COMMENT: A number of specimens, fundamentally comparable with *P. australiensis* Deflandre and Cookson from Onepah Station, New South Wales, have been recovered from residues of the Eyre No. 1 Bore core 20. All have shown very clearly the radial folds in the wing of the shell, mentioned by Deflandre and Cookson 1955, p. 286 in the original description of this species, and shown in the illustration of the type specimen, Pl. 9, fig. 4. On this account, therefore, there seems to be no justification for the separation of the better preserved Eyre specimens from *P. australiensis* nor for the formation of the new species *P. helios* Sarjeant (1959) from the Upper Jurassic Cornbrash of Yorkshire.

A feature not mentioned by Deflandre and Cookson or by Sarjeant is the presence in a few of the Eyre Bore specimens (Pl. 10, fig. 5, 6) of a small circular thickening in the centre of one side of the shell.

***Pterospermopsis centrata* n. sp.**

(Pl. 10, fig. 7, 8, Holotype fig. 7 F8093)

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore No. 1 core 20, Western Australia.

DIMENSIONS: Holotype fig. 7, overall diameter c. 66  $\mu$ , shell c. 35  $\mu$ , ventral thickening c. 20  $\mu$ . Range: Overall diameter c. 60-66  $\mu$ , diameter of shell c. 32-35  $\mu$ , central thickening c. 18-20  $\mu$ .

DESCRIPTION: The holotype, which is circular in outline, consists of a relatively wide and thick outer wing-like layer and an inner portion which probably represents the shell proper. The latter consists of a series of zones, the outermost of which is the widest and most delicate. The centre of the shell is occupied by a thick-walled circular body with a small round and solid central area, very similar to the one present in *Pterospermopsis australiensis*.

***Pterospermopsis zonaria* n. sp.**

(Pl. 10, fig. 9, 10, Holotype fig. 9 F8095)

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore No. 1 core 20.

DIMENSIONS: Holotype, overall diameter c. 46  $\mu$ , shell c. 17  $\mu$ . Range of overall diameter: c. 32-65  $\mu$ .

DESCRIPTION: Specimens flat, circular in outline with indications of several concentric layers and apparently composed, as in other species of *Pterospermopsis*, of a central shell and an equatorial wing. However, in this species, without a cross-section through the centre it is not possible to determine the actual limits of the shell and wing.

***Pterospermopsis eurypteris* Cookson and Eisenack 1958**

(Pl. 10, fig. 11)

*Pterospermopsis eurypteris* Cookson and Eisenack 1958, p. 49, Pl. 9, fig. 9, 13.

*Pterospermopsis eurypteris* Cookson and Eisenack, Alberti 1961, p. 40, Pl. 11, fig. 10.

COMMENT: Three specimens which seem referable to *P. eurypteris* have been recovered from the Eyre Bore sample 20, the main distinction being one of size. For example, the overall diameter of the three Eyre specimens recovered range from c. 58-72  $\mu$  and the diameter of the shell between c. 24  $\mu$  and c. 28  $\mu$ , whereas the overall diameter of the original examples of *P. eurypteris*, from Western and South Australian Lower Cretaceous deposits, ranged from between c. 95  $\mu$  and c. 123  $\mu$  and the shells between c. 36  $\mu$  and c. 49  $\mu$ .

**Sub-group Uncertain**

**Genus *Palaeostomocystis* Deflandre 1935**

***Palaeostomocystis pachythea* n. sp.**

(Pl. 11, fig. 7-9, Holotype fig. 8 F8109, Paratype fig. 7 P8110)

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore No. 1 core 20.

DIMENSIONS: Holotype c. 34  $\times$  35  $\mu$ . Range: c. 28-35  $\mu$ . Wall of shell c. 2-5  $\mu$  thick.

DESCRIPTION: Shell small, circular to slightly oval in outline, smooth, unornamented and typically thick-walled. Opening by the detachment of the whole apical wall of the shell.

COMMENT: The Eyre Bore specimens, herein tentatively referred, as a new species, to the genus *Palaeostomocystis*, appear to be somewhat similar to the specimens from Pleistocene Peats in Staffordshire, England, referred by Sarjeant and Strachan 1968 to the genus *Leiosphaeridia* Eisenack 1958 emend Downie and Sarjeant 1963. However, the Eyre specimens differ from *L. telmaticum* Sarjeant and Strachan in the somewhat larger size of the shell, the greater thickness of the wall and the wider and more strongly outlined opening. The example shown in Pl. 5, fig. 9 has a thinner wall and may, possibly, represent a distinct species of *Palaeostomocystis*.

**Group and Family Incerta**

***Enigmasphaera eyrensis* n. gen. n. sp. F8081**

(Pl. 9, fig. 5)

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore No. 1 core 20, Western Australia.

DIMENSIONS: Overall shell c. 90  $\mu \times$  95  $\mu$ .

DESCRIPTION: Shell roughly circular in outline, with

four marginal concavities which mark the limits between the four large areas into which one surface of the shell is delimited by somewhat thickened, slanting and entire lines which extend from the centre of the wall to the outer margins. On the opposite surface, four areas are also evident; two large ones square in outline and two smaller ones which, unfortunately, are less clearly delimited. All four are outlined by small closely arranged dot-like thickenings. The general surface of the shell is otherwise completely smooth and unornamented and its wall is moderately thick.

COMMENT: Only one specimen has been found. There is no evidence that the shell was hollow.

### Class Fossil CHLOROPHYTA

#### ? Order VOLVACEALES Oltmanns 1904

#### Family LECANIACEAE Cookson and Eisenack 1970b

DIAGNOSIS: 'Shell single-layered, circular to slightly oval in outline, which when mature, apparently separates into two half-spheres each of which is flat and widely open on one side; with or without ornamentation and with or without a thin wing'.

Type Genus *Lecaniella* Cookson and Eisenack 1962a, p. 270

Genus *Eyrea* Cookson and Eisenack 1970b, p. 322

DIAGNOSIS: 'Shell circular to slightly oval in outline, smooth or finely granular, surrounded by a thin, hyaline wing which is indistinctly and irregularly delimited. Usually the two half-shells occur as individual units only occasionally side by side in pairs' as in Pl. 11, fig. 3, 5. Type species *Eyrea nebulosa* n. sp.

*Eyrea nebulosa* n. sp.

(Pl. 11, fig. 2-6, Holotype fig. 2 F8099, Paratypes fig. 9 F8100 and fig. 11 F8101)

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore No. 1 core 20.

DIMENSIONS: Holotype: Shell c.  $51 \mu \times 50 \mu$ , overall diameter c.  $65 \mu$ . Range of shells: c.  $33-52 \mu$ .

DESCRIPTION: Shell circular to slightly oval in outline, smooth or very finely and indistinctly granular, surrounded by a thin, hyaline wing which is indistinctly and irregularly delimited and occasionally finely and radially striated. Sometimes the outermost rim of the shell seems to be tilted over and, due to compression, appears as a narrow double zone. Usually the two half-shells occur as individual units, only occasionally side by side in pairs (Pl. 11, fig. 3, 5).

*Eyrea* sp.

(Pl. 11, fig. 1 F8098)

DIMENSIONS: Shell c.  $140 \mu \times 119 \mu$ , wing c.  $218 \mu \times 166 \mu$ .

COMMENT: The figured half-shell, the only one of its kind found, suggests that a second species of this genus may have occurred in the Eyre deposit. It is much larger than specimens of *E. nebulosa* and the shell is distinctly granular.

#### ? Order PROTOCOCCALES Manum & Cookson 1964

#### Family Uncertain

Genus *Palambages* O. Wetzel 1961

*Palambages* cf. Form A Manum and Cookson 1964

(Pl. 11, fig. 12 F8104)

*Palambages* Form A Manum and Cookson 1964, p. 24, Pl. 7, fig. 3-6.

*Palambages* Form A Manum and Cookson, Cookson 1965, p. 91, Pl. 11, fig. 5, 6.

AGE AND OCCURRENCE: Mid-Cretaceous, Eyre Bore No. 1 core 20, Western Australia.

DIMENSIONS: Overall diameter c.  $45-90 \mu$ , individual cells c.  $22-24 \mu$ , number per colony c. 8-100.

COMMENT: The Eyre examples of *Palambages* agree closely with those of Form A from Graham and Ellef Ringes Island (Manum and Cookson 1964) and Upper Cretaceous deposits in Eastern Australia (Cookson 1965). In all the Australian specimens the walls of the shells have been thin 'smooth or very finely granular in surface view'.

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## EXPLANATION OF PLATES 7-11

## PLATE 7

- FIG. 1—*Cribroperidium edwardsi* (Cookson and Eisenack) Davey 1969, p. 125,  $\times$  c. 280.  
 FIG. 2-3—*Deflandrea eyrensis* n. sp. Fig. 2, Paratype,  $\times$  c. 550; Fig. 3, Holotype,  $\times$  c. 550.  
 FIG. 4—*Deflandrea ingrani* Cookson and Eisenack 1970a,  $\times$  c. 550.  
 FIG. 5-6—? *Ascodinium trendalli* Cookson and Eisenack 1970a,  $\times$  c. 750.  
 FIG. 7-9—*Microdinium ornatum* Cookson and Eisenack 1960,  $\times$  c. 750.  
 FIG. 10—*Microdinium veligerum* (Deflandre) Davey 1969,  $\times$  c. 700.  
 FIG. 11—*Microdinium* sp.,  $\times$  c. 700.

## PLATE 8

- FIG. 1-2—*Hystrichosphaera ramosa* (Ehrenberg 1838) var. *ramosa* Davey and Williams 1966,  $\times$  c. 350.  
 FIG. 3—*Cyclonephelium membraniphorum* Cookson and Eisenack 1962,  $\times$  c. 250.  
 FIG. 4—*Cyclonephelium reticulosum* Gerlach 1961,  $\times$  c. 350.  
 FIG. 5—*Cyclonephelium distinctum* Deflandre and Cookson 1955, emend Cookson and Eisenack 1962b.  
 FIG. 6—*Canningia circularis* n. sp. Holotype,  $\times$  c. 500.  
 FIG. 7—*Oligosphaeridium pulcherrimum* (Deflandre and Cookson) 1955, Davey and Williams 1966,  $\times$  c. 300.

## PLATE 9

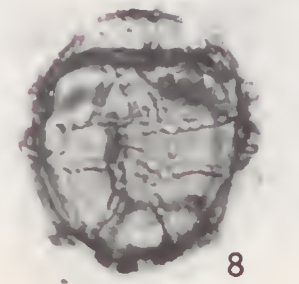
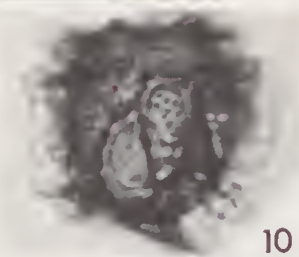
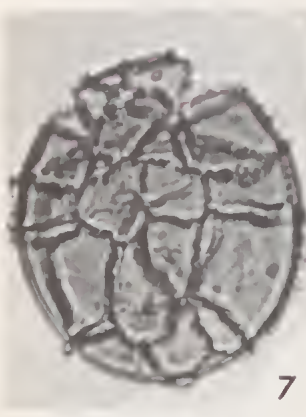
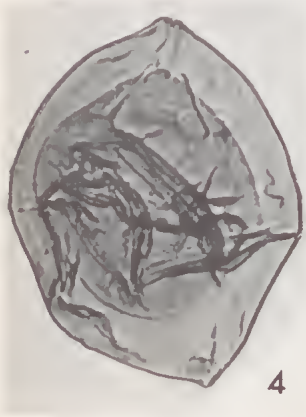
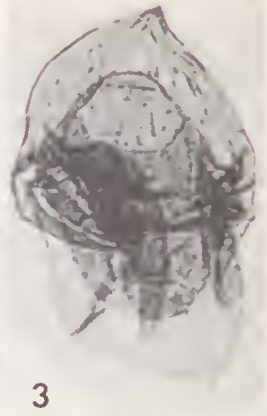
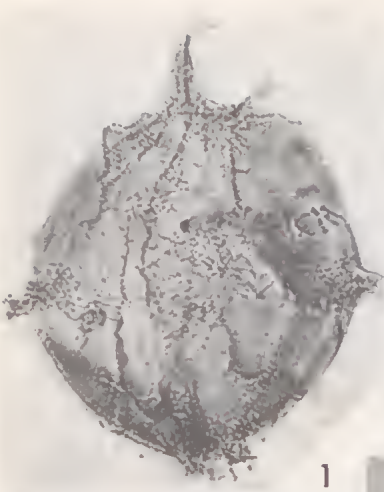
- FIG. 1—*Chlamydothorella nyei* Cookson and Eisenack 1958,  $\times$  c. 750.  
 FIG. 2, 3—? *Chlamydothorella* sp. Fig. 2,  $\times$  c. 800; Fig. 3,  $\times$  c. 600.  
 FIG. 4—*Diplofusa gearlensis* Cookson and Eisenack 1960,  $\times$  c. 400.  
 FIG. 5—*Eyreasphaera enigmatica* n. gen., n. sp.,  $\times$  c. 375.  
 FIG. 6—? *Operculodinium punctatum* n. sp. Holotype,  $\times$  c. 500.  
 FIG. 7, 8—? *Operculodinium rarispinosum* n. sp. Fig. 7, Holotype,  $\times$  c. 700; Fig. 8, Paratype,  $\times$  c. 1,000.  
 FIG. 9, 11—*Cymatiosphaera* sp. Fig. 9, 10 two views of the same specimen,  $\times$  c. 550; Fig. 11,  $\times$  c. 700.  
 FIG. 12-14—*Cymatiosphaera tremaphora* n. sp.,  $\times$  c. 700. Fig. 12, Holotype; Fig. 13, Paratype.

## PLATE 10

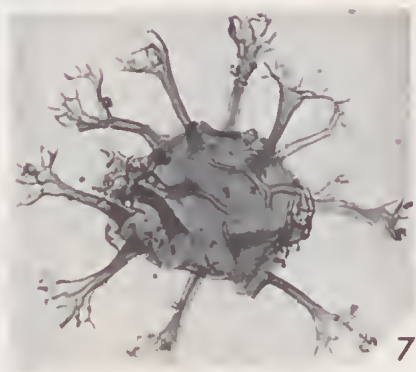
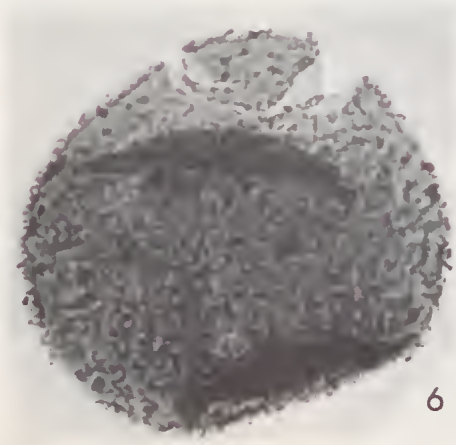
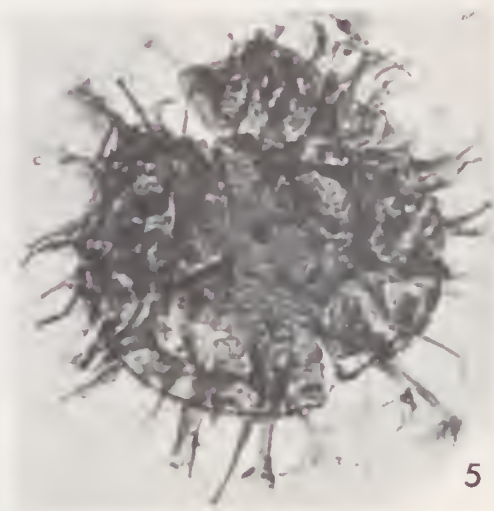
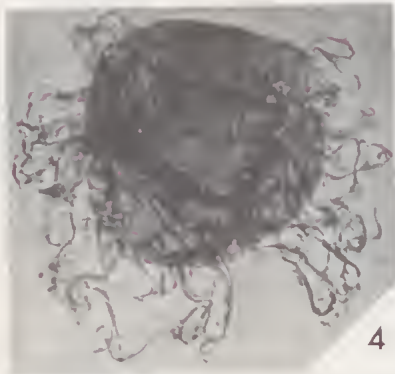
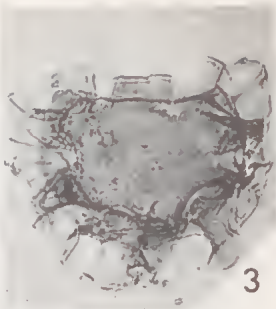
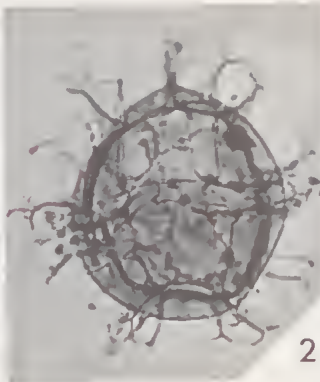
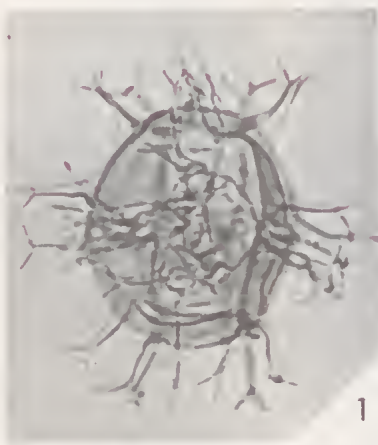
- FIG. 1-3—*Pterospermopsis aureolata* Cookson and Eisenack 1958. Fig. 1,  $\times$  c. 250; Fig. 2, 3,  $\times$  c. 700.  
 FIG. 4—*Pterospermopsis* cf. *australiensis* Deflandre and Cookson 1955.  
 FIG. 5, 6—*Pterospermopsis australiensis* Deflandre and Cookson 1955,  $\times$  c. 380.  
 FIG. 7, 8—*Pterospermopsis centrata* n. sp. Fig. 7, Holotype,  $\times$  c. 330; Fig. 8,  $\times$  c. 670.  
 FIG. 9, 10—*Pterospermopsis zonaria* n. sp. Fig. 9, Holotype,  $\times$  c. 670; Fig. 10,  $\times$  c. 670.  
 FIG. 11—*Pterospermopsis eurypteris* Cookson and Eisenack 1958,  $\times$  c. 670.  
 FIG. 12-14—*Cymatiosphaera delicata* n. sp. Fig. 12-14,  $\times$  c. 550; Fig. 13, Holotype.

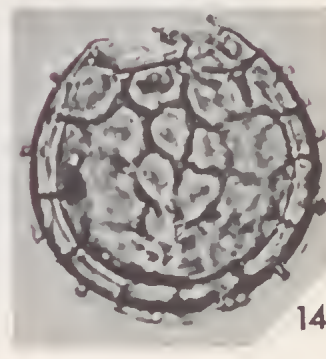
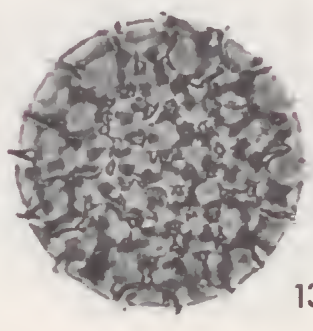
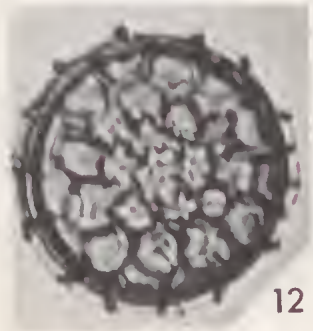
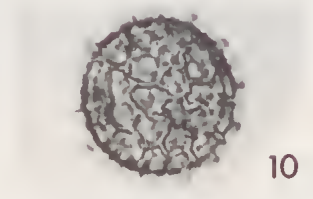
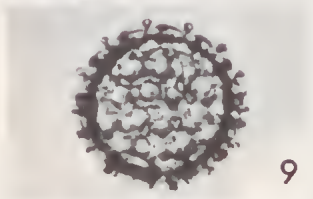
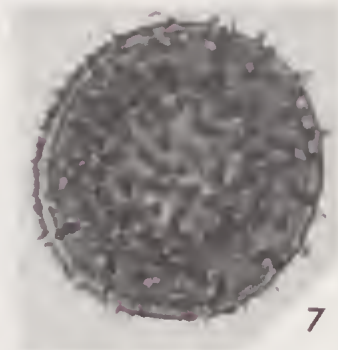
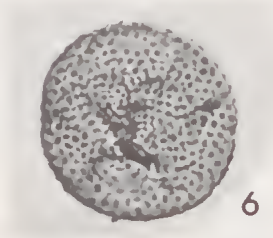
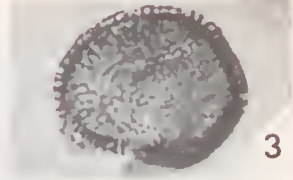
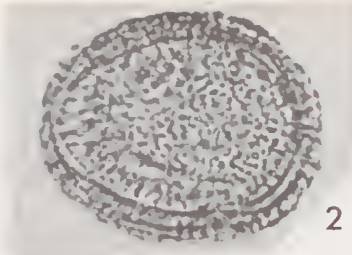
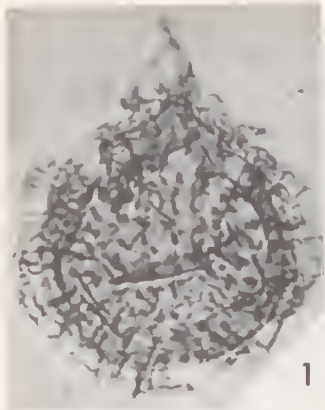
## PLATE 11

- FIG. 1—*Eyrea* sp.,  $\times$  c. 285.  
 FIG. 2-6—*Eyrea nebulosa* n. sp. Fig. 2, Holotype,  $\times$  c. 800; Fig. 3-4, 6,  $\times$  c. 570; Fig. 5,  $\times$  c. 240.  
 FIG. 7-9—*Palaeostomocystis pachytheca* n. sp.,  $\times$  c. 750. Fig. 8, Holotype.  
 FIG. 10—*Cleistosphaeridium* cf. *polytrichum*,  $\times$  c. 600.  
 FIG. 11—? *Exosphaeridium* affinity *striolatum*,  $\times$  c. 800.  
 FIG. 12—*Palambages* cf. Form A Manum and Cookson,  $\times$  c. 650.



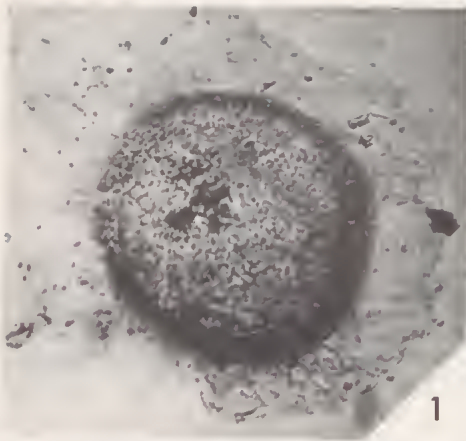




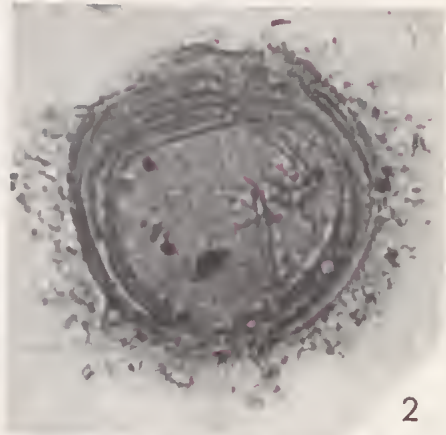




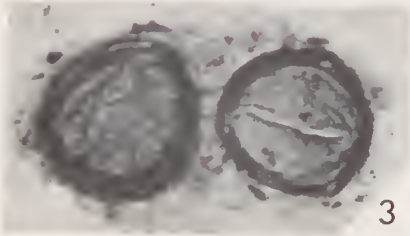




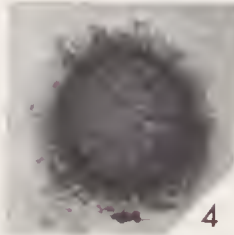
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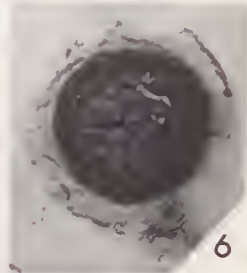
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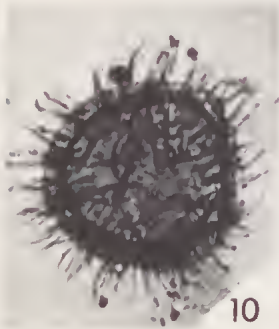
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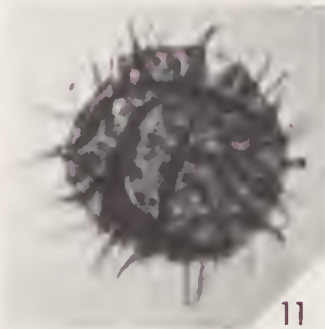
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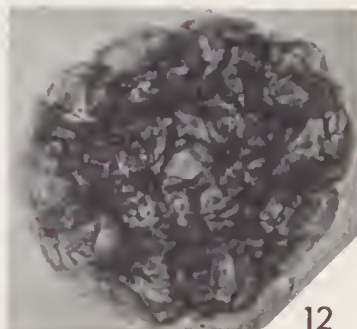
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## A RE-ASSESSMENT OF THE TERTIARY ECHINOID GENUS *GONIOSIGMA* FELL 1964

By G. M. PHILIP\*

**ABSTRACT:** The holotype of the New Zealand temnopleurid *Echinus enysi* Hutton, type species of *Goniosigma* Fell 1964 is described and figured. As a consequence *Asaphechinus* Philip 1969 is regarded as a junior synonym, and the following four Australian Tertiary species are referred to *Goniosigma*: *Asaphechinus murrayensis* Philip, *A. princeps* Philip, *A. singletoni* Philip, *A. tasmanensis* Philip.

### INTRODUCTION

The Tertiary temnopleurid genus *Goniosigma* Fell 1964 was proposed for *Echinus enysi* Hutton 1873, from Oligocene strata of the Trelissic Basin, New Zealand. In describing the Tertiary temnopleurids from SE. Australia (Philip 1969, pp. 248-249) only passing reference was made to this genus, for, from the description of the genus, no close relationship appeared to exist with Australian forms. Through the courtesy of Dr. G. R. Stevens, of the Geological Survey of New Zealand, it has now been possible to study the holotype of *Echinus enysi* Hutton and an additional specimen identified as *Goniosigma enysi* in the Geological Survey's collections. The purpose of this note is to redescribe and illustrate this material and, on this basis, comment on the relationships of the genus.

### SYSTEMATIC DESCRIPTION

Genus *Goniosigma* Fell

Type Species *Echinus enysi* Hutton 1873

**DESCRIPTION OF HOLOTYPE:** Geol. Surv. N.Z. EC272 (Pl. A, fig. 2-3, 6).

Test fragmentary, with adapical portion largely missing and with most of peristome obscured by matrix. Comparatively large and depressed with a flattened adoral surface somewhat sunken around the peristome. Gill slits (revealed by preparation) small and sharp and prominently buttressed by a ridge.

Ambulacra slightly greater than half of the width of the interambulacra. Poriferous tract narrow, with the pore-pairs in each triad distinctly arcuate. The primary ambulacral tubercles form a regular vertical series and are mounted close to the poriferous tract. A small secondary tubercle is mounted between the median pore-pair of each triad and its primary tubercle. Elsewhere the secondary tubercles tend to

be irregular although towards the ambitus a slightly enlarged secondary tubercle may be present inside the primary ambulacral tubercles. The pores within each pore-pair are equal in size.

The interambulacral plates possess small median primary tubercles similar in size to the corresponding ambulacral tubercles. A horizontal series of slightly enlarged secondary tubercles is present along the middle of each plate. Beneath the ambitus, these secondary tubercles are more enlarged and prominent. The remainder of the surface of the plates is covered with irregular granules which may coalesce to form vermiculate ridges parallel to the median suture. Both the median ambulacra and interambulacral sutures tend to be bare above the ambitus.

Although the test is worn and has poorly preserved surface detail, the primary ambulacral and interambulacral tubercles are coarsely crenulate and their bosses are irregularly scalloped.

**DESCRIPTION OF GEOL. SURV. N.Z. EC697 (Pl. A, fig. 1, 4-5).**

**LOCALITY:** 'Trig M, near Totara, Oamaru', from tuffs under Oamaru Limestone.

**DESCRIPTION:** Test well preserved but broken and lacking apical system and one-third of adoral surface. Test moderately large and depressed with a flattened adoral surface sunken around the peristome. Gill slits small, sharp and well buttressed. Perignathic girdle poorly preserved and broken but consisting of low apophyses connecting wide, high auricles apparently united above the ambulacra.

Ambulacra approximately half of the width of the interambulacra. Poriferous tract narrow with the pore-pairs of each triad arranged in obscure arcs which become more pronounced toward the ambitus. The primary ambulacral tubercles are small and are mounted adjacent to the poriferous tract where they form a regular vertical series. The secondary tubercles are irregularly disposed and the median suture is bare down to the ambitus.

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## MEASUREMENTS:

No.	h.d.	v.d.	Diameter apical system	Diameter peristome	No. ambs.	No. interambs.
EC272	29.0 mm	c. 16.0 mm	—	—	c. 23 (24)	c. 18 (19)
EC697	19.5	11.0	5.5 mm	8.5 mm	16 (17)	13 (14)

The interambulacral plates possess median primary tubercles similar in size to the corresponding ambulacral tubercles. A horizontal series of slightly enlarged secondary tubercles is present along the middle of each plate. At and beneath the ambitus these become more prominent. The remainder of the surface of the plates is covered with tubercles and irregular granules which become more crowded toward the ambitus. Adapically the median interambulacral suture tends to be bare.

The tubercles are coarsely crenulate and the bosses of the primary tubercles tend to be scalloped.

## REMARKS:

1. The tubercles of the holotype of *Echinus enysi* Hutton are not smooth (as described by Fell 1964) but are coarsely crenulate.

2. Although the nature of the apical system and of the girdle cannot be determined from the holotype, the ambulacra, gill-slits and ornament closely ally the species with *Asaphechinus murrayensis* Philip, the type species of *Asaphechinus* Philip 1969.

3. As a consequence, *Asaphechinus* is here regarded as a subjective junior synonym of *Goniosigma* Fell 1964.

4. The following Australian Tertiary temno-pleurid species are here transferred to *Goniosigma*: *Asaphechinus murrayensis* Philip 1969, pp. 242-243, Pl. 5, fig. 1-4, 6-7, 12; Pl. 12, fig. 5; Text-fig. 2a-c, e-g.

*Asaphechinus princeps* Philip 1969, pp. 243-244, Pl. 5, fig. 8-10; Pl. 12, fig. 5; Pl. 14, fig. 1-3; Text-fig. 3c, e, g.

*Asaphechinus singletoni* Philip 1969, pp. 244-246, Pl. 6, fig. 1-4, 8-12; Pl. 12, fig. 3-4; Pl. 13, fig. 4; Text-fig. 3a-b, f, h-i.

*Asaphechinus tasmanensis* Philip 1969, Pl. 6, fig. 5-7; Pl. 15, fig. 2; Text-fig. 8g-h, j.

5. *Goniosigma enysi* resembles most closely the Australian species *G. princeps*, but differs in that

- (a) the test is sunken around the peristome,
- (b) the pores in each pore-pair are of similar size,
- (c) the subambital secondary interambulacral tubercles are not so large.

6. *G. princeps* may show vermiculate granules forming ridges parallel to the median interambulacral suture, the feature on which Fell based the genus *Goniosigma* (cf. Philip 1969, Pl. 5, fig. 10). The feature is variable and does not occur in all specimens of *G. princeps*. Moreover it does not occur in all species of *Goniosigma*.

7. A second specimen in the collections of the Geological Survey of New Zealand (EC697) was identified by Fell as *Goniosigma enysi*.

8. In this specimen the pore-pairs are not markedly arcuate. However the nature of the perignathic girdle is suggestive of *Asaphechinus* (= *Goniosigma*) rather than *Cryptechinus*. The specimen would appear to represent a species close to *G. tasmanensis*, but further material is necessary for the species to be properly determined. For the present it is identified *Goniosigma* ? sp. indet.

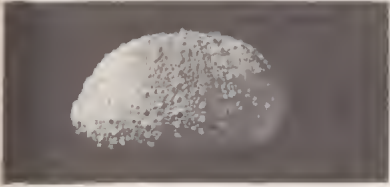
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## EXPLANATION OF PLATE 12

Figures  $\times 1.5$  approximately, unless otherwise stated

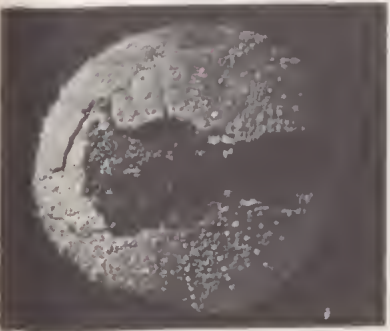
- FIG. 2-3, 6—*Goniosigma enysi* (Hutton). (2) Lateral; (3) Adapical view of holotype, N.Z. Geol. Surv. EC272; (6) Enlargement of superambital ornament,  $\times 10$  approx.  
 FIG. 1, 4-5—*Goniosigma* ? sp. indet. (1) Lateral; (2) Adapical view of N.Z. Geol. Surv. EC697; (5) Enlargement of superambital ornament,  $\times 10$  approx.



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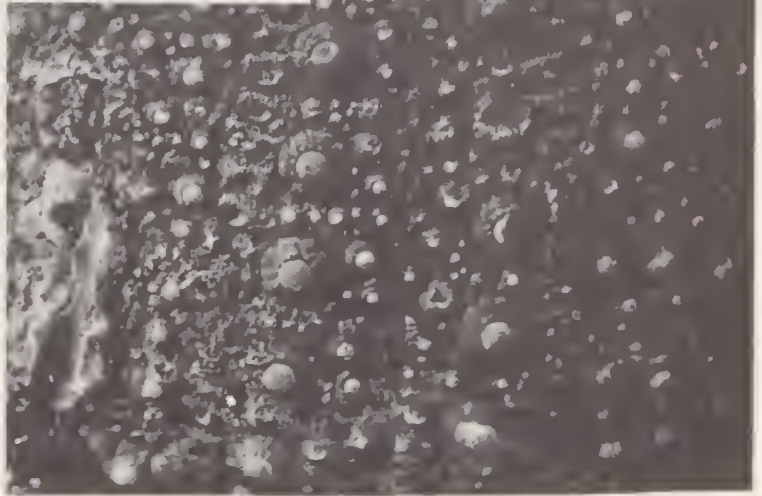
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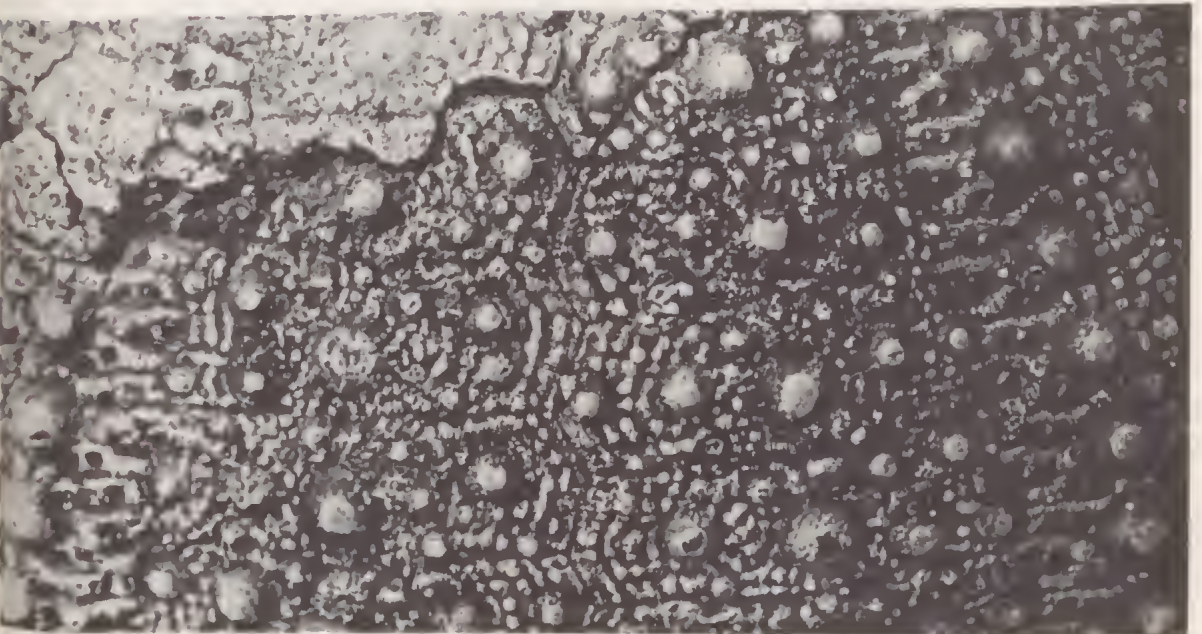
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## A RE-EVALUATION OF THE FROMM'S LANDING THYLACINE TOOTH

By M. ARCHER\*

**ABSTRACT:** Reasons are given for considering that the Fromm's Landing thylacine tooth (A 57204) probably represents an individual conspecific with the modern *Thylacinus cynocephalus*. Certain dental abnormalities in thylacinid, dasyurid and macropodid teeth are considered. The functional significance of anterolingual cusp development in some placental and marsupial teeth is discussed.

### INTRODUCTION

A small thylacine tooth (South Australian Museum No. A 57204) from an archaeological excavation in a rock shelter at Fromm's Landing, South Australia, is described and illustrated by Macintosh and Mahoney, in an Appendix to Mulvaney, Lawton and Twidale (1964). Macintosh and Mahoney concluded that this tooth differed from the eighteen modern specimens of *T. cyno-*

*cephalus* available to them by its 'miniature size, bifid protocone, absence of a definitive style C<sub>2</sub>', and the 'presence of a minute style buccally on the extremity of the metaeonal spur . . .'. They decided that these differences 'when summated, prevent inclusion of the Fromm's Landing tooth in *T. cynocephalus*'. However, they also expressed the opinion that specific determination would be premature because there was only one tooth.

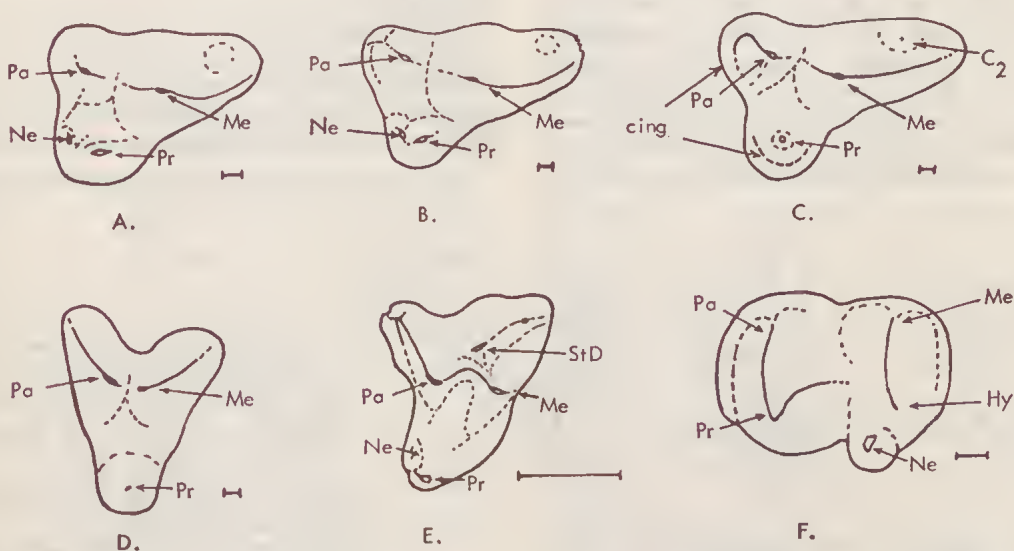


FIG. 1—Dental abnormalities in thylacine and other marsupial teeth. A. Fromm's Landing thylacine A 57204, LM<sup>1</sup> (adapted from Macintosh and Mahoney 1964); B. *Thylacinus cynocephalus* M 0138, LM<sup>1</sup>; C. *Thylacinus* sp., Wellington Caves, N.S.W., RM<sup>1</sup> (reversed and shown as LM<sup>1</sup>); D. *Thylacinus* sp., Wellington Caves, N.S.W., RM<sup>1</sup>; E. *Antechinus flavipes* M 8092, LM<sup>2</sup>; F. *Macropus irma* M 6526, LM<sup>1</sup>. Abbreviations: Pr = protocone; Pa = paracone; Me = metacone; Hy = hypocone (topographic); Pcl = protoconulc; Mcl = metaconulc; Ne = neomorph cusp; StD = stylar cusp D (stylar cusp C of Slaughter 1968); C<sub>2</sub> = stylar cusp C<sub>2</sub> of Macintosh and Mahoney (1964) and originally of Bensley (1903); cing = cingulum; Plc = posterolingual cingulum. Each bar measure represents approximately one millimetre in length.

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I have been able to examine this tooth (Fig. 1A) and conclude, for reasons set out below, that it can in fact represent an individual of the species *T. cynocephalus*. I use the dental symbolism of Ride (1964). All catalogue numbers unless otherwise noted are those of the Western Australian Museum Mammal Collection.

## THE DENTAL CHARACTERS

### *The 'bifid protocone'*

I have examined the only two modern thylacine specimens, and all the fossil thylacine specimens available for study in the Western Australian Museum. Besides minor variations in dental morphology, I have observed in one modern thylacine (M 0138) the presence of a small anterolingual cusp on the flank of the protocone of the LM<sup>1</sup> and the LM<sup>2</sup>, and the almost total absence of stylar cusp C<sub>2</sub> on the LM<sup>1</sup> (Fig. 1B). In one isolated thylacine RM<sup>1</sup> from the Wellington Cave deposits in New South Wales there is a distinct anterior cingulum (Fig. 1C). In another isolated RM<sup>4?</sup> (homology uncertain) from the same deposit there is an abnormal distribution of cusps (Fig. 1D). Abnormalities in molar structure in other marsupials are not uncommon, particularly among phascogaline dasyurids. In a specimen of *Antechinus flavipes* (M 8092) which I bred in captivity, there is a distinct small anterolingual cusp on the LM<sup>2</sup> (Fig. 1E). In a specimen of *Sminthopsis macroura* (Queensland Museum specimen J 7407) there is a small cusplule developed on the anterolingual side of the LM<sup>1</sup> and LM<sup>2</sup>. Similarly, one specimen of modern *Macropus irma* (M 6526) exhibits an extra cusp lin-

gual to the topographic hypocone of the L and RM<sup>1</sup> (Fig. 1F).

It is clear that abnormal lingual cusp development does occasionally occur in individuals of fossil and modern thylacine populations, as well as individuals of various other marsupial groups. Similar supernumerary lingual cusp development occurs in placentals, as for example the Carabelli cusp in human dentitions. This has an incidence rate which evidently varies racially, but occurs among more than 40% of Caucasians (Van Reenen 1967).

### *The 'definitive style, C<sub>2</sub>'*

There is no cusp in this position on the LM<sup>1</sup> of the modern thylacine specimen M 0138 (Fig. 1B). However, there is a bulge on the crown in the area where the cusp would normally develop and where the cusp is developed on the RM<sup>1</sup> of the same specimen. There is a similar bulge on the Fromm's Landing tooth, although it is not as prominent.

### *The 'small buccal style on the extremity of the metaconal spur'*

I do not consider that there is a significant cusp in this position on the Fromm's Landing tooth. If there is a swelling in this position, it is no better developed than it is in the modern thylacine specimen M 0138.

### *The 'miniature size'*

Mrs. J. W. J. Lowry, who will shortly publish an analysis of certain small thylacines, has kindly supplied the following statement on the size of the Fromm's Landing thylacine tooth (A 57204):

I have compared my measurements of the Fromm's

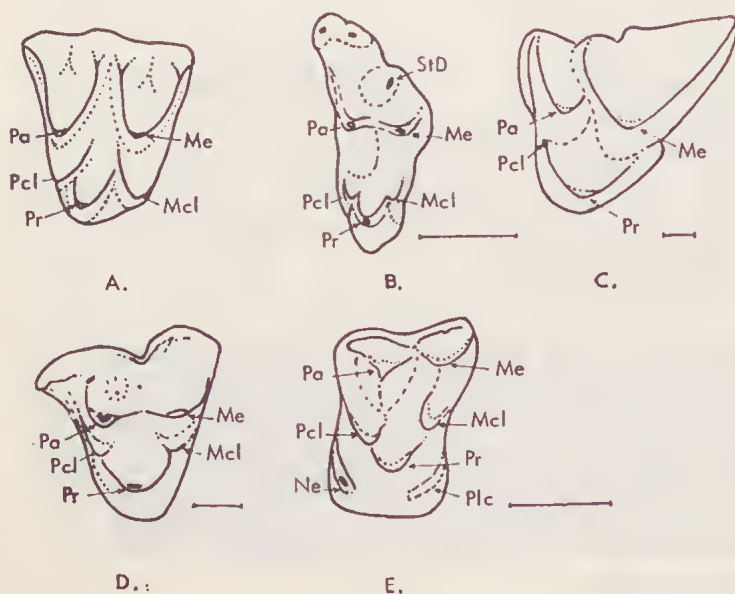


FIG. 2.—Protoconule and neomorphic cusp development. A. *Desmana* (after Mills 1966); B. *Clemensia* (modified from Slaughter 1968, reversed and shown as a LM<sup>4</sup>) RM<sup>4</sup>; C. *Dasyurus maculatus* M 3855, LM<sup>2</sup>; D. *Alphadon* (modified from Clemens 1966) LM<sup>2</sup>; E. *Nyctitherium* (modified from McKenna 1960, reversed and shown as a LM<sup>1</sup>) RM<sup>1</sup>. Abbreviations as in Fig. 1. Each bar measure represents approximately one millimetre in length.



Landing thylacine tooth with the dimensions of the M's from the remains of 7 thylacines from caves in the Eucla Division of Western Australia (Lowry and Lowry, 1967; Partridge, 1967), and conclude that its length is contained in the range of lengths observed in the Eucla Division sample. Mean dimensions of dental characters from this Eucla Division sample are smaller than those of a sample of thylacine remains from caves in the southwest of Western Australia, but in most characters the difference is not statistically significant at the 5 per cent level. Ride (1964) considered that his southwestern sample, although statistically significantly smaller than modern *Thylacinus cynocephalus* in many characters, did not represent a separate species of *Thylacinus*. The remains considered here are believed to be all Recent to late Pleistocene in age (Merrilees, 1968), and there is no good reason to believe that they do not represent a single species that was more variable in the past. Thus the marked smallness of the Fromm's Landing thylacine tooth does not seem to be sufficient reason alone to separate it from *T. cynocephalus*.

## DISCUSSION

The Fromm's Landing tooth, from a level dated at approximately 4,000 years BP (Macintosh and Mahoney 1964) may represent the extant species *T. cynocephalus*, or some other valid species now extinct. Several species of *Thylacinus* have been described, namely *T. cynocephalus*, *T. spelaus*, *T. rostralis* and *T. potens*. Only the first three of these are accepted as being Quaternary in age. Ride (1964) analysed characters of Pleistocene and Recent thylacines and concluded that there is no statistical basis for the separation of *T. cynocephalus* and *T. spelaus* into more than one species. However, Ride pointed out that the measurements of some specimens from Darling Downs and New Guinea may indicate the presence of one or more additional species and suggested that the Darling Downs specimens may represent the characters of *T. rostralis* De Vis. Van Deusen (1963) comments on the New Guinea thylacine specimen but does not suggest that it necessarily represents an undescribed species.

J. Lowry has suggested (above) that the small size of the Fromm's Landing tooth seems insufficient reason to conclude that it does not represent *T. cynocephalus*, and I have shown above that the three remaining characters discussed by Macintosh and Mahoney (1964) are not unique to the Fromm's Landing tooth but are features also of the modern thylacine specimen M 0138. However, since I have seen no specimen of any thylacine species in which the 'bifid protocone' is as distinct as it is in the Fromm's Landing tooth, this may be a character which could be distinguished as representative of a separate species. There are thus two reasonable interpretations of

this structure: 1. It is in fact an abnormality of dubious or minimal taxonomic significance such as are the structural abnormalities noted above in molars of other species or; 2. It represents a significant development characteristic of an extinct population of thylacines. We will consider both alternatives.

If the cusp is a significant functional and characteristic feature of a species of *Thylacinus* we may be able to determine what this function may have been by considering lingual cusp development in other species. Enlargement of the metaconule has been a feature of marsupial evolution, as for example in the perameline peramelids, glabrine didelphids and probably the marsupial diprotodont herbivores. In these forms, the cusp I interpret as the enlarged metaconule functions as a topographic hypocone analogous with the polyphyletic hypocones of various placentals. Enlargement of a topographic anterolingual protoconule is not uncommon among placental insectivores such as *Desmana* (Fig. 2A) but a significant enlargement of this cusp is virtually unknown among marsupials, although it is present in such Cretaceous forms as *Clemensia* (Fig. 2B), *Alphadon* (Fig. 2D) and other didelphine didelphids. It is miniscule in most dasyurids (Fig. 2C) and peramelids. In addition to protoconule development, there are some instances of neomorphic anterolingual cusp development in placentals, such as in one specimen of a species of the Eocene genus *Nyctitherium* (Fig. 2E). Here the neomorph clearly has nothing to do with the well-developed topographic protoconule. Although I suspect that the anterolingual cusp in the Fromm's Landing tooth is a protoconule, the question of homology is less significant than that of function. The cusp may as well be considered a neomorph as is surely the case in the specimen of the species of *Nyctitherium*. Mills (1966) suggests that certain minor cusps such as the protoconule and mesostyle may act as stops at the end of grooves to prevent spillage of food. This is presumably one function of the protoconule in *Desmana* and possibly in the Cretaceous didelphids. Such a protoconule that confines food would be a useful feature in dentitions that are wholly or partly adapted for pulverizing. The food particles are maintained on an occlusal crushing surface for a greater amount of the time involved in mastication than they are in a dentition adapted largely for vertical shearing. In shearing the emphasis is placed on efficient slicing of tough or resilient food. Talon development restricts the depth or amount of the vertical shear by producing an impediment against which the talonid occludes. For example, the absence of talonid or



conule development in the marsupial mole *Notoryctes* results in almost unlimited vertical shearing potential, whereas the production of topographic hypocones and anterolingual cusps commonly reduces the amount of vertical shear. In extreme conditions such as in hominids (Crompton and Hiiemae 1969) and vombatids vertical molar shear is virtually eliminated. In the species of *Nyctitherium* exhibiting anterolingual cusp development the neomorphic cusp would probably restrict vertical shear, but because of its low and peripheral position on the crown may not have acted as a 'stop' as does the protoconule of *Desmana*. Rather, it might have served a double function by providing a ramp for the lower molar after it approaches centric position to help initiate the lingual phase of chewing, as well as by providing a lateral shear surface with a corresponding portion of the lower molar. In the modern thylacine specimen M 1038 the anterolingual cusp does not clearly serve any of these functions. It is not at the end of a groove to act as a stop, nor is it large enough to affect the trigonid or provide a lateral shearing surface. It is perhaps more appropriately considered as an anterior bulge on the protocone. On the other hand, the anterolingual cusp of the Fromm's Landing tooth is considerably larger and could act as a confining structure around the small protoconal basin. It probably did not affect the trigonid because of its proximal position to the protoconal basin and its small size compared with the neomorphic cusp of the specimen of the species of *Nyctitherium*. The tip of this cusp exhibits wear, but because it is the same type of coarse wear pattern exhibited by the major trigon cusps I would conclude that this was wear due to the abrasion of food particles rather than to occlusion. The cusp does not therefore appear to provide a lateral shearing surface.

In favour of the other alternative, that the cusp is an abnormality of minimal or dubious taxonomic significance, is the evidence presented above for the clearly abnormal appearance of a similar cusp in a modern specimen of the dasyurid species *Antechinus flavipes*, and the abnormal appearance of a similar but less developed neomorphic cusp in a specimen of the modern *Thylacinus cynocephalus*. Further evidence for the suggestion that it is an abnormality is provided by Kurtén (1967) who demonstrated that in samples of fossil ursid populations from caves, dental variation was higher in juvenile skulls than it was in adult skulls. He interpreted this as evidence for selection against certain dental variation. The Fromm's Landing tooth does not represent an old individual. Similarly, the abnormal modern thylacine is a young animal with the M<sup>3</sup> just erupting.

Finally, it is worth considering that one of the major characteristics of the thylacinids is their protocone-talonid reduction and consequent development of long and high shearing crests. Since it is reasonable to assume that this is a derived condition from a more generalized didelphoid (or possibly dasyurid) condition, it would mean that if the anterolingual cusp under discussion is a development with adaptive significance, some thylacinids are now (M 0138) and have been (Fromm's Landing tooth) undergoing a reversal of this trend and producing a more significant talon-talonid development. It is perhaps curious that if this is so, it should be so comparatively rare in modern thylacines. It is also curious that no other fossil thylacine specimens known to me from the Nullarbor or south-west or south-east Australia, which probably bracket the age of the Fromm's Landing tooth, exhibit this character. However the possibility that it is not an abnormality cannot be discounted on this evidence alone.

## CONCLUSIONS

It is most probable that the Fromm's Landing thylacine molar represents an individual conspecific with the modern *Thylacinus cynocephalus*.

This conclusion is based on the fact that the structures it presents are not unique and are represented in part as abnormalities in a modern thylacine specimen and also in one character by a specimen of the dasyurid species *Antechinus flavipes*. It is conceivable, however, that the presence of the anterolingual neomorphic cusp in the Fromm's Landing tooth is characteristic of an as yet unknown thylacine population. The cusp could be functional and hence adaptive. The possibility cannot be discounted on the basis of negative evidence or improbability. On the other hand, there is positive evidence to suggest that the cusp is an abnormality in *T. cynocephalus* (as in M 0138) and hence the Fromm's Landing tooth should not be considered to differ significantly from the modern species on the basis of this character.

## ACKNOWLEDGMENTS

I wish to thank Dr. W. D. L. Ride and Dr. D. Merrilees of the Western Australian Museum and Mrs. J. W. J. Lowry for constructively criticizing the manuscript; Dr. M. McKenna of the American Museum of Natural History, Dr. M. O. Woodburne of the University of California at Riverside, and Mr. R. Bower of the University of Western Australia for their helpful comments; Mrs. J. A. J. Lowry for her communication concerning the size of the Fromm's Landing tooth. Mr. G. L. Pretty

of the South Australian Museum kindly allowed the tooth to be examined. I was supported during the research of this project by a Fulbright Scholarship.

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# THE STROMATOPOROID GENERA *ACTINOSTROMA* NICHOLSON AND *NEXILILAMINA* GEN. NOV. FROM THE DEVONIAN BROKEN RIVER FORMATION, NORTH QUEENSLAND

By C. W. MALLET\*

**ABSTRACT:** Five species of *Actinostroma*, including one new species *A. steloges*, are described, from Middle Devonian Members of the Broken River Formation. Specimens of *A. clathratum* Nicholson and *A. papillosum* are distinguished by considering the number of pillars and laminae measured in 5 mm, and the gallery index of specimens. *Nexililamina* gen. nov. is proposed to embrace species with laminae composed of thin sheets of compact tissue, which may in places combine to form complex laminae. The type species of the new genus is *N. dipcreekensis* sp. nov.

## INTRODUCTION

Stromatoporoids are common in the limestone members of the Broken River Formation on Pandanus Creek Station, Shield Creek Holding, North Queensland. The Collection area is situated approximately at latitude 19°13'S. and longitude 144°45'E.

Most of the fossils described are from the Chinaman Creek Limestone Member and the Dip Creek Limestone Member (Jell 1968) of the Broken River Formation, with a few specimens from isolated rudites within the Broken River Formation. Fossils are stored in the School of Geology and Mineralogy, University of Queensland, and are catalogued with University Fossil Numbers (e.g. F.47607) and Fossil Locality Numbers (e.g. L.2979). A description of each fossil locality is given in Appendix.

## SUBGENERIC DIVISIONS OF *ACTINOSTROMA*

Ripper (1938) divided the species of *Actinostroma* into three groups, based on the structure of the laminae and the continuity of pillars. Lecompte (1951) described five groups of species, but he included only those forms found in the Middle and Upper Devonian of the Ardennes, Belgium. Flügel (1959) in his review of the genus considered all described species of *Actinostroma*, and arranged them in eight groups within two subgenera. Nestor (1964) erected the genus *Plectrostroma* Nestor, to include those species of *Actinostroma* grouped with *A. intertextum* Nicholson

by Flügel and characterized by thin discontinuous laminae.

Most of the specimens described here can be arranged in two of the species groups proposed by Ripper, Lecompte and Flügel. The group of *A. stellulatum* Nicholson is characterized by specimens with well-developed laminae, long pillars, rectilinear galleries, and usually more than seven pillars and laminae in 1 mm. This group is represented by the nominate species only. The second group is *A. clathratum* Nicholson, characterized by well-developed laminae, long pillars, rectilinear galleries, and usually fewer than 5 laminae and pillars per mm. Representatives of this group are *A. clathratum*, *A. papillosum* (Bargatzky), and *A. dehornae* Lecompte. *A. steloges* sp. nov. does not conform to any of the proposed groupings. The group of *A. verrucosum* proposed by Lecompte is represented, and is described as a new genus, *Nexililamina*.

## SPECIATION

Workers have used many different features as specific characters in *Actinostroma*, but Flügel (1959) rejected all criteria except the structure and spacing of the laminae and pillars. He used 'Art diagram' and 'Art feld' to define numerically and graphically the variation in the number of pillars and laminae in 1 mm of a vertical section of a stromatoporoid coenosteum. Extreme variants are eliminated by the use of the 'maximum', which includes all values of the 'art diagram' that occur at least twice in ten measurements. For example,

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if ten measurements gave values 3, 4, 4, 5, 5, 5, 5, 6, 6, 7 the 'maximum' is [4-6]. The 'maximum' describes limits within which most of the measurements of a species lie. The method of Flügel for defining species has not been used, as the small number of pillars and laminae in 1 mm mask the differences between and within coenosteae.

Klovan (1966) introduced a new index to aid in distinguishing species, the gallery index, which is the average ratio of the heights of galleries to their lengths. The gallery index may be measured directly, or calculated from the thickness and spacing of the pillars and laminae.

In most cases, species of *Actinostroma* are readily identified by measuring the distribution of pillars and laminae, which yield clear groupings of values corresponding to species. With the species *A. dehornae*, *A. papillosum* and *A. clathratum*, this is not possible. The arrangement of pillars and laminae in all species appears similar, and the variation in the spacing of the skeletal elements of *A. papillosum* overlaps that of *A. dehornae*, and falls within that of *A. clathratum*.

Lecompte (1951) stated when he proposed *A. devonense* (= *A. papillosum*) that it could be distinguished from *A. clathratum* by the spacing of the pillars. Flügel (1959), however, considered that the two species could be distinguished by the spacing of laminae rather than pillars. All workers have distinguished *A. dehornae* on the basis of the widely spaced laminae, which are also differentiated in zones, closely and distantly spaced.

In separating the species of this collection, dimensions of fossils were determined, to see if one or a combination of characters could provide a guide to speciation. Commonly ten measurements were taken of each character in each coenosteum. The characters measured were: number of laminae in 5 mm vertical section, number of pillars in 5 mm vertical section, number of pillars in 1 mm<sup>2</sup> tangential section, thickness of laminae, diameter of pillars, and (calculated from these) the gallery index of Klovan (1966). The results of these measurements have been synthesized and are reported in the descriptions of the species. Data for each character are given in the following form:

M = The mean value of all measurements taken in each species (equal number of measurements in each specimen).

σM = The standard deviation of the mean values of individual coenosteum, from the overall mean of the species.

σm = The average of the standard deviations within coenosteae from their respective means.

When these measurements were obtained, it

was clear that there were present in the collection specimens which could be allocated to *A. dehornae*, *A. papillosum*, and *A. clathratum*. All the mean values for individual coenosteae were plotted on 'pillars in 5 mm versus laminae in 5 mm' and 'pillars in 1 mm<sup>2</sup> versus laminae in 5 mm' graphs, but no obvious separation of species resulted. The values of the gallery indices for the specimens were then superimposed on these plots. It was possible to divide the collection into groups with characteristic gallery index curves on the pillar/laminar plots. This allowed a distinction to be drawn between specimens with the same distribution of pillars and laminae, but whose gallery index differed because of different thicknesses of pillars and laminae. These differences could not commonly be detected qualitatively, and required measurements to be made for them to be established.

## SYSTEMATIC DESCRIPTIONS

### Genus *Actinostroma* Nicholson 1886

*Actinostroma* Nicholson 1886, p. 75; Ripper 1937, p. 12; 1938, p. 222; Flügel 1959, p. 123; Stearn 1966, p. 86.

TYPE SPECIES: *Actinostroma clathratum* Nicholson 1886, p. 76, Pl. 1, fig. 11-13; 1886a, p. 226, Pl. 4, fig. 1-3, from the Middle Devonian (Givetian of Gerolstein, West Germany).

DIAGNOSIS: Coenosteae are composed of well-developed laminae and pillars. Pillars are continuous and traverse many laminae. Laminae are composed of arms which radiate from the pillars and unite to form an hexactinellid network, which is usually apparent in tangential section. Tissue is compact. Astrorhizae and dissepiments are present.

RANGE: *Actinostroma* is known from the Lower Silurian of Europe, Middle and Upper Silurian of Europe, Asia, and North America, and is cosmopolitan in the Devonian.

### *Actinostroma dehornae* Lecompte

(Pl. 13, fig. 3, 5)

*A. dehornae* Lecompte 1951, p. 96, Pl. 4, fig. 1-4; Zúkalová 1958, p. 319, Pl. 2, fig. 1-2; Flügel 1959, p. 140, Pl. 7, fig. 1.

HOLOTYPE: Specimen number 4136 in Lecompte's collection in The Royal Institute of Natural Sciences, Brussels, collected from the Upper Devonian, Frasnian of Surice, Belgium.

DIAGNOSIS: Coenosteae are globular and may have well-developed latilaminae. Laminae are continuous, 0.05 to 0.10 mm thick, and the average number in 5 mm for each coenosteum generally ranges from 10 to 20. The laminae are irregularly zoned and are arranged in zones of greater and lesser density. The diameter of the continuous pillars ranges from 0.10 to 0.20 mm, the average number in 5 mm for each coenosteum ranges between 10 and 20, and the aver-



age number in 1 mm<sup>2</sup> ranges from 7 to 11. The gallery index lies between 1.0 and 1.5.

**DESCRIPTION OF BROKEN RIVER SPECIMENS:** Coenostea are globular. The tissue is melanospheric or flocculent, sometimes with dark-coloured axial zones in the laminae.

In vertical section laminae are continuous, with the thickness means for the coenostea ranging from 0.05 to 0.07 mm ( $M = 0.057$ ,  $\sigma M = 0.009$ ). The laminae undulate gently but irregularly, and are irregularly spaced. The surfaces of some specimens show a zonation which corresponds to areas in the coenostea where laminae are more closely or more distantly spaced. These zones average 1 mm in width and the numbers of laminae in 1 mm can be as low as 3 where they are distantly spaced, or 8 where they are closely arranged. The zones are not present in all specimens and are weakly developed in others. The average number of laminae in 5 mm for each coenosteam ranges from 19 to 21 ( $M = 19.9$ ,  $\sigma M = 0.8$ ,  $\sigma m = 1.1$ ). Pillars are continuous and straight, with an average diameter for each coenosteam ranging from 0.10 to 0.17 mm ( $M = 0.123$ ,  $\sigma M = 0.025$ ). The average number of pillars in 5 mm varies between 12 and 14 ( $M = 13.0$ ,  $\sigma M = 0.58$ ,  $\sigma m = 0.84$ ). Laminae are upturned around occasional astrophorizal systems, which average 6 mm in diameter. Galleries are rectangular, show very little rounding at the corners, and have a gallery index of from 1.3 to 1.5 ( $M = 1.44$ ,  $\sigma M = 0.08$ ).

In tangential section, circular cross-sections of pillars are joined by faint arms in an hexactinellid network, where laminae are intersected. The arms are usually destroyed by recrystallization. The average number of pillars in 1 mm<sup>2</sup> for each coenosteam ranges from 8 to 11 ( $M = 8.8$ ,  $\sigma M = 0.78$ ,  $\sigma m = 0.71$ ). There are five specimens in the collection.

**REMARKS:** Lecompte (1951) justified the erection of this species by the irregularity of the laminae and their tendency to be arranged in groups more closely and more distantly spaced. The Broken River specimens agree well with the holotype of the species in the degree of development and distribution of pillars and laminae, but the grouping of laminae in more closely and more distantly spaced bands is less pronounced (see Pl. 13, fig. 5).

*A. dehornae* has fewer pillars in 5 mm and 1 mm<sup>2</sup> than either *A. clathratum* or *A. papillosum*, and specimens of it have higher gallery indices than both other species. When the gallery indices are contoured on a pillar laminar plot, they show a continuation of the values of *A. clathratum*, and are much higher than those of *A. papillosum*. This suggests that *A. dehornae* and *A. papillosum* have both arisen from a common ancestor, *A. clathratum*. Specimens were assigned to *A. dehornae* if the average number of pillars was less than approximately 14 in 5 mm and 11 in 1 mm<sup>2</sup> and the gallery index 1.3 or more.

**RANGE:** The species has been reported from the Frasnian of Belgium (Lecompte 1951), and Givetian and Frasnian of Czechoslovakia (Zukalová 1958, and Dvůrák, Chlupac & Svoboda 1958). It was found in

the Chinaman Creek Limestone Member of the Broken River Formation, on the traverse along Chinaman Creek South, 500 m upstream from the base of the Member (L.2510).

#### *Actinostroma clathratum* Nicholson

(Pl. 13, fig. 2, 4)

*Actinostroma clathratum* Nicholson 1886, p. 76, Pl. 1, fig. 11-13; Lecompte 1951, p. 77, Pl. 1, fig. 1-12 Flügel 1959, p. 129.

**LECTOTYPE:** Specimen No. 141/P.5774 in the British Museum (Natural History) illustrated by Nicholson (1886, Pl. 1, fig. 11), selected by Schouppé (1954, p. 431), and collected from the Middle Devonian of Gerolstein, West Germany.

**DIAGNOSIS:** Coenostea are globular, encrusting or laminar. Laminae and pillars form a regular network with pillars usually thicker than laminae. Pillars are long, with a diameter of approximately 0.06 to 0.12 mm, and the average number in 5 mm in vertical section usually ranges between 20 and 25. Strong continuous laminae are generally 0.04 to 0.12 mm thick, and the average number in 5 mm for each coenosteam usually lies between 20 and 25. In tangential section there are usually 15 to 28 pillars in 1 mm<sup>2</sup>.

**DESCRIPTION OF BROKEN RIVER SPECIMENS:** Coenostea are globular, laminar, or encrusting. Low undulations are present on the surface, but no well-developed mamelons are present. In rare specimens where the tissue is well preserved, the laminae and pillars are composed of yellow compact tissue, which is, however, commonly altered to a melanospheric or flocculent condition.

In vertical section laminae are continuous, evenly curved and spaced, with the mean thickness for the coenostea ranging from 0.03 to 0.07 ( $M = 0.054$ ,  $\sigma M = 0.012$ ). The average number in 5 mm for each coenosteam ranges from 13 to 28 ( $M = 21.0$ ,  $\sigma M = 2.7$ ,  $\sigma m = 1.2$ ). Pillars are long and continue through many laminae with an average diameter varying from 0.06 to 0.12 mm ( $M = 0.10$ ,  $\sigma M = 0.019$ ). The average number in 5 mm ranges between 15 and 28 ( $M = 20.0$ ,  $\sigma M = 2.9$ ,  $\sigma m = 1.1$ ). Galleries are rounded at their corners and the mean calculated gallery index for the collection is 0.90 ( $\sigma M = 0.23$ ). The value of the gallery index corresponding to the number of laminae and pillars is shown in Fig 1 and 2. Thin, curved dissepiments are present in the galleries.

In tangential section laminae occur as perforated sheets of tissue or as dense hexactinellid networks, depending on the degree of alteration. Pillars are roughly circular in cross-section. The average number of pillars in 1 mm<sup>2</sup> ranges between 11 and 28 ( $M = 17.8$ ,  $\sigma M = 4.9$ ,  $\sigma m = 1.0$ ). Thin, curved dissepiments in places join pillars. Astrophorizae average 5 mm in diameter and their centres are 8 mm apart; the astrophorizae have groups of axial canals approximately 0.09 mm diameter. There are 25 specimens in the collection.

**REMARKS:** Specimens of *A. clathratum* which have a



similar number of laminae and pillars in 5 mm to *A. papillosum* are distinguished by higher gallery indices (i.e. more horizontally elongated galleries). This can be seen by comparing Fig. 1 with Fig. 3. These show the change in the value of the gallery index with the change in the numbers of pillars and laminae in 5 mm and 1 mm<sup>2</sup>, for *A. clathratum* and *A. papillosum*. The use of Fig. 1-4 in separating specimens into *A. clathratum* and *A. papillosum* is illustrated by comparing the values of the gallery index in both species for 15 pillars and 20 laminae in 5 mm in vertical section. The value for *A. papillosum* is 0.95 (see Fig. 3) and 1.25 for *A. clathratum* (Fig. 1). The differing gallery index for corresponding numbers of pillars and laminae separates the two species over most of the range of variation in the species; however, where the value of the gallery index is around 0.9, and the number of laminae in 5 mm is less than twenty, it is difficult to place the specimen confidently in either species.

No detailed measurements of the characters of the lectotype, and the rest of Nicholson's original collection in the British Museum (Natural History) have been published, but Lecompte (1951) listed generalized measurements. From these measurements the gallery indices were calculated, and the specimens compared with this collection. The lectotype of *A. clathratum* (see Fig. 1 and 2) has more closely spaced pillars and laminae than most of the specimens in this collection, and the gallery index is higher. This may be the result of inadequate data. When Nicholson's collection in the British Museum (Natural History) is examined (based only on Lecompte's data) according to the criteria outlined above, Nos. 141 (Lectotype), 142, 144, 145, 150, 151, and 154 are

allocated to *A. clathratum*, and Nos. 148, 149 and 153 to *A. papillosum*.

RANGE: Flügel (1959) reviewed the literature concerning this species, and concluded that it occurs most commonly in the Givetian and the Frasnian, but also is present in the Couvinian. The species is very widespread, and is reported from England, Belgium, Germany, Italy, North Africa, U.S.S.R., Czechoslovakia, Southwest China, and Western Australia (Flügel and Flügel-Kahler 1968). In the Broken River Formation this species is found throughout the Chinaman Creek Limestone Member along Chinaman Creek South (L.2509, L.2510, L.2976), and from 150 m SW. of the base of the Dip Creek Limestone Member, to its top, on the Martin's Well traverse, 1 km SW. of Martin's Well (L.2978, L.2980, L.2984).

#### *Actinostroma papillosum* (Bargatzky)

(Pl. 13, fig. 1)

*Stromatopora papillosa* Bargatzky 1881, p. 281.

*A. clathratum* var. 2 and var. 3 Nicholson 1889, p. 131, Pl. 12, fig. 2-3.

*A. devonense* Lecompte 1951, p. 88, Pl. 2, fig. 3-6, Pl. 3, fig. 1-3.

*A. papillosum* (Bargatzky); Flügel 1959, p. 167.

LECTOTYPE: Selected by Flügel (1959): *Stromatopora papillosa* Bargatzky (1881), specimen number 5 in Bargatzky's collection, Museum of the Institute of Geology and Palaeontology, University of Bonn, collected from the Givetian of 'Schladetal', Paffrath-Mulde, West Germany, illustrated by Lecompte (1951), Pl. 1, fig. 11.

DIAGNOSIS: Coenostea are globular or laminar, and latilaminae may be present. Laminae arc continuous,

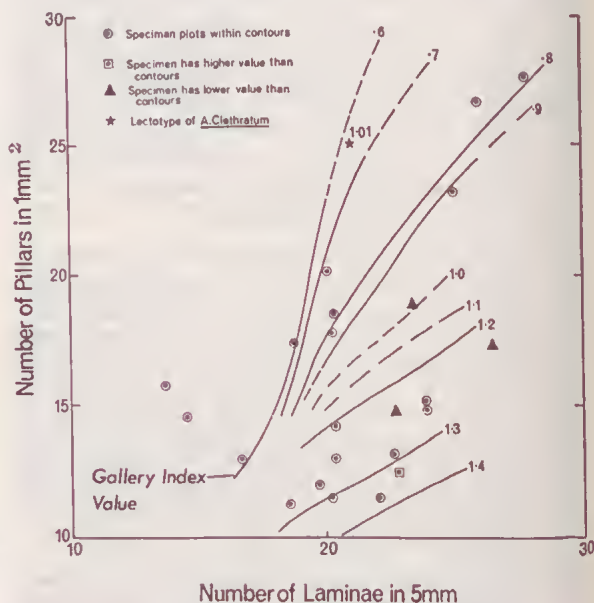
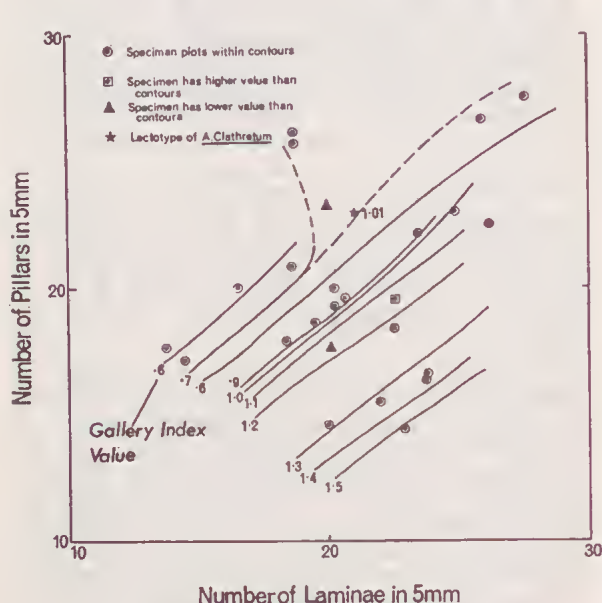


FIG. 1, 2—The variation of gallery index with the distribution of pillars and laminae in *A. clathratum* Nicholson.

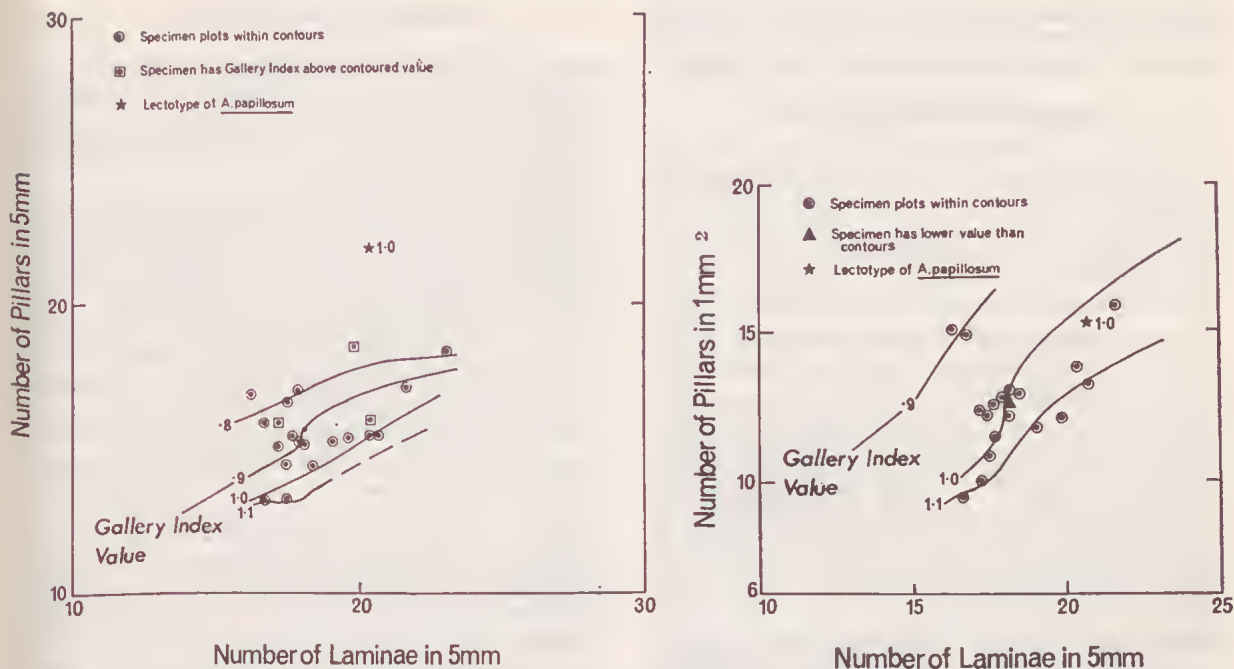


FIG. 3, 4—The variation of gallery index with the distribution of pillars and laminae in *A. papillosum* (Bargatzky).

usually 0.03 to 0.10 mm thick, with the average number in 5 mm generally between 15 and 23, and they may be irregularly spaced in some places. Pillars are long and continuous, with a diameter of approximately 0.08 to 0.12 mm, and the average number in 5 mm usually ranges from 15 to 25. The average number in 1 mm<sup>2</sup> is commonly from 10 to 15. The gallery index is approximately 1.

**DESCRIPTION OF BROKEN RIVER SPECIMENS:** Coenostea are globular or laminar. The tissue is commonly flocculent or melanospheric and has formed from the alteration of the originally compact tissue.

In vertical section laminae are strong and continuous and range in thickness from 0.03 to 0.08 mm ( $M = 0.052$ ,  $\sigma M = 0.014$ ). The average number in 5 mm ranges from 16 to 23 ( $M = 18.5$ ,  $\sigma M = 1.4$ ,  $\sigma m = 0.97$ ). Pillars are long and continuous with a diameter from 0.08 to 0.12 mm ( $M = 0.11$ ,  $\sigma M = 0.01$ ), and the average number in 5 mm ranges from 13 to 19 ( $M = 15.7$ ,  $\sigma M = 1.0$ ,  $\sigma m = 0.9$ ). Galleries are slightly rounded at the corners and the average gallery index for the collection is 0.98 ( $\sigma M = 0.09$ ).

In tangential section laminae are represented by areas where the hexactinellid network is prominently developed. Pillars are isolated in some areas of the sections, but the greater part of any slide is occupied by the hexactinellid network, where pillars are joined to their neighbours by 3 to 6 arms in a rigid pattern. Pillars are approximately circular in cross-section and the average number in 1 mm<sup>2</sup> ranges from 9 to 17 ( $M = 12.7$ ,  $\sigma M = 1.4$ ,  $\sigma m = 0.88$ ). Obseure astro-rhizal systems, 8 to 10 mm apart, consist of an axial

canal with radiating branches. There are 22 specimens in the collection.

**REMARKS:** Lecompte (1951) reviewed Nicholson's collection of *A. clathratum* and equated *A. clathratum* var. 2 and 3 of Nicholson with a new species, *A. devonense* Lecompte. He considered that specimens described as *Stromatopora papillosa* by Bargatzky (1881) belonged to *A. clathratum* var. 1 of Nicholson, basing his conclusion on the number of laminae and pillars in 5 mm. Flügel (1959), in his review, considered that *S. papillosa* Bargatzky corresponded to *A. c.* var. 2 and 3, on the basis of the 'maximum' and that the specific name *papillosa* had precedence over *clathratum* and *devonense*. The position of the lectotype chosen for *A. papillosum* (Bargatzky) by Flügel is not clear. The numbers of pillars and laminae in 5 mm certainly seem very similar to the lectotype of *A. clathratum* s. str., but the numbers of pillars in 1 mm<sup>2</sup> given by Lecompte (1951) are much lower. The specimen has been plotted on Fig. 3 and 4 and it can be seen that it does not correspond well with the collection here assigned to *A. papillosum*; in fact it is very close to the lectotype of *A. clathratum* (see Fig. 1). In Fig. 4 there is much better agreement with the present collection. The lectotype needs more careful description before it can be definitely established as synonymous with *A. clathratum*. If the lectotype is maintained separate from *A. clathratum*, it is certainly at the limit of the species here assigned to *A. papillosum* for which Lecompte established *A. devonense*.

**RANGE:** *A. papillosum* is found only in the Chinaman



Creek Limestone Member of the Broken River Formation, from 500 to 1,000 m W. of the base of the Member on Chinaman Creek South (L.2510, L.2976).

*Actinostroma stellulatum* Nicholson

(Pl. 13, fig. 6, 7)

*A. stellulatum* Nicholson 1892, p. 231, Pl. 6, fig. 8-9; Lecompte 1951, p. 111, Pl. 11, fig. 1-5; Flügel 1959, p. 179 (*pars*).

*A. stellulatum* var. *maureri* Lecompte 1951, p. 118, Pl. 12, fig. 1-3.

*A. perlaminatum* Lecompte 1951, p. 120, Pl. 12, fig. 4.

HOLOTYPE: Specimen No. 170/P5570 in the British Museum (Natural History) London, collected from the Givetian of Gerolstein, West Germany.

DIAGNOSIS: Coenostea are globular or laminar and latilaminae may be present. Laminae are evenly curved and spaced, usually with an average of 28 to 35 in 5 mm. Pillars are straight and continuous, the average number in 5 mm generally ranges from 28 to 35. In 1 mm<sup>2</sup> in tangential section, the average number usually lies between 35 and 45. The gallery index is approximately 0.75.

DESCRIPTION OF BROKEN RIVER SPECIMENS: Coenostea are globular or laminar, some with large mamelons 12 mm apart and 5 mm high. Tissue is compact, but may have altered to a flocculent condition in parts of the coenostea.

In vertical section laminae are strongly developed with an average thickness of 0.05 mm, and the average number in 5 mm ranges from 24 to 32 ( $M = 27.3$ ,  $\sigma M = 2.6$ ,  $\sigma m = 1.2$ ). Pillars are continuous and regularly spaced with an average diameter of from 0.06 to 0.08 mm ( $M = 0.069$ ); the average number in 5 mm ranges between 28 and 33 ( $M = 28.5$ ,  $\sigma M = 0.8$ ,  $\sigma m = 1.4$ ). Galleries are rounded at their corners and have an average gallery index of 0.73 ( $\sigma M = 0.02$ ). Astrorhizae are not apparent, but in the axial regions of mamelons there are a few thin dissepiments.

In tangential section laminae are concentrically arranged around mamelons. Laminae are composed of perforated sheets of compact tissue in which radial arms 0.05 mm thick are in places developed. Pillars are round in cross-section and the number in 1 mm<sup>2</sup> ranges between 38 and 41 ( $M = 39.4$ ,  $\sigma M = 1.1$ ,  $\sigma m = 1.9$ ). There are three specimens in the Broken River collection.

REMARKS: This species is distinguished from the other species of *Actinostroma* in the collection by the much larger number of pillars present in 1 mm<sup>2</sup> in tangential section.

RANGE: *A. stellulatum* has been described from Belgium, Germany, England, U.S.S.R., and North America, from strata ranging in age from Couvinian to Frasnian (see Flügel 1959: 185). In the Broken River Formation it occurs in the Dip Creek Limestone Member (Couvinian) on Dip Creek 2.4 km upstream from the junction of Dip Creek and Pandanus Creek (L.2499). It occurs also in isolated rudites (Couvinian?).

*Actinostroma steloges* sp. nov.

(Pl. 14, fig. 1-3)

HOLOTYPE: Fossil numbered F.47755 from the Couvinian Dip Creek Limestone Member of the Broken River Formation, 800 m SW. of the base of the Member, 1 km SW. of Martin's Well, Pandanus Creek Station, North Queensland.

DIAGNOSIS: Coenostea are globular with irregular low undulations, and latilaminae may be present. Laminae are 0.12 to 0.2 mm thick and are pierced by some large pores. There are from 9 to 14 laminae in 5 mm. Pillars are continuous and their diameter ranges from 0.22 to 0.28 mm, with from 9 to 13 in 5 mm. There are from 17 to 24 pillars in 4 mm<sup>2</sup> in tangential section. Galleries are rounded to subrounded, and the gallery index ranges from 0.5 to 1.0. Dissepiments occur in the galleries and astrorhizae are not present.

DESCRIPTION: The coenostea are discoidal or globular, with undulating laminae but no mamelons. Latilaminae are developed 5 mm apart. The tissue is compact, but rarely is fibrous in the laminae. In the holotype, the pillars have a dark lumen. It is possible that there has been slight alteration and that these types of tissues have developed from an originally compact tissue.

In vertical section laminae are commonly continuous, slightly irregularly spaced, and they range in thickness from 0.12 to 0.20 mm ( $M = 0.16$ ,  $\sigma M = 0.02$ ). In some areas the laminae appear to be discontinuous, and are replaced by thin dissepiments. The average number of laminae in 5 mm for each coenosteam ranges from 9 to 14 ( $M = 12.3$ ,  $\sigma M = 1.4$ ,  $\sigma m = 0.75$ ). Pillars are continuous, and the average number in 5 mm ranges from 9 to 13 ( $M = 10.6$ ,  $\sigma M = 0.95$ ,  $\sigma m = 0.76$ ). The average pillar diameter for coenostea ranges from 0.22 to 0.28 mm ( $M = 0.25$ ,  $\sigma M = 0.02$ ). Galleries are rounded to subrounded, 0.16 to 0.23 mm high, and have an average gallery index from 0.5 to 1.0 ( $M = 0.80$ ,  $\sigma M = 0.15$ ). Dissepiments are concentrated in bands 2 mm thick and approximately 5 mm apart.

In tangential section laminae occur as sheets of perforated tissue or zones of radial arms. The cross-section of pillars is circular, with their diameter smallest at the centre. The pillars are spool-shaped. The average number in 4 mm<sup>2</sup> for each coenosteam ranges between 17 and 24 ( $M = 20.0$ ,  $\sigma M = 2.0$ ,  $\sigma m = 1.8$ ). An incipient astrorhizal system appears to be developed in one specimen. There are four specimens in this collection.

REMARKS: This species has thicker and more distantly spaced skeletal structures than any other described species of *Actinostroma* (Gr. *στυλο* = pillar, *μεγα* = large); the only species approaching the dimensions of *A. steloges* is *A. ingens* Ünsalander (1951) which should be removed to *Nexililamina* gen. nov. as mentioned in the discussion below.

Klován (1966, p. 19, Pl. 4, fig. 1) described a species, *A. redwaterense*, which has a somewhat similar appearance to *A. steloges*, but the fewer number of pillars and laminae in 5 mm in vertical section



in *A. steloges* readily distinguishes it from *A. redwaterense*.

*A. steloges* is, however, very similar to the species described as *Gerronostroma concentricum* Yavorsky (1931). The microstructure of the holotype of the type species of *Gerronostroma* is in doubt, as no descriptions other than those of Yavorsky have been published, and he maintains that the tissue is compact. The paratype described by Galloway (1957) has fibrous tissue. If the tissue of *G. concentricum* is compact, then this new species may be synonymous with *G. concentricum*. The two species have very similar spacing and thicknesses of skeletal structures, and both occur in Couvinian strata.

**RANGE:** *A. steloges* occurs in the Couvinian Dip Creek Limestone Member of the Broken River Formation, 800 m SW. from its base, to the top of the Member on the Martin's Well traverse, 1 km south-west of Martin's Well (L.2982).

#### *Nexililamina* gen. nov.

**TYPE SPECIES:** *Nexililamina dipcreekensis* sp. nov.: holotype F.47608, from the base of the Dip Creek Limestone Member, Broken River Formation, 1 km SW. of Martin's Well, Pandanus Creek Station, North Queensland; Couvinian.

**DIAGNOSIS:** Coenostea are composed of well-developed pillars and laminae. Pillars are commonly continuous or continuously superimposed. Laminae may be composed of simple perforated sheets of compact tissue, or closely spaced system of microlaminae, forming a single complex lamina. Parts of coenostea show completely *Actinostroma*-like structure in vertical section. Radial arms joining pillars are not developed, but laminae in places are perforated. Astrorhizae are present.

**REMARKS:** This genus embraces those species which Lecompte (1951) placed in a group of *A. verrucosum*, and similar species which subsequently have been described. The genus is closely related to *Actinostroma*, and only differs in possessing complex combined laminae (*L. nexilis* = tied together, *lamina* = plate), the lack of radial arms, and the pillars frequently split beneath laminae which are widely spaced. In some parts of vertical sections of coenostea, the structure is completely analogous to that of *Actinostroma*. The holotype of the type species of *Actinostroma*, *A. clathratum*, shows some grouping of laminae but they always form simple sheets of hexactinellid network.

*Atelodictyon* Lecompte can be distinguished from *Nexililamina* by its discontinuous pillars confined to a single interlaminary space, and laminae which are composed of simple sheets of compact tissue arranged in a hexactinellid network.

*Anostylostroma* Parks also has pillars which are restricted to one interlaminary space, but the tissue of the laminae is not compact.

Species assigned to this genus include: *N. verrucosa* (Goldfuss) (1826) Couvinian to Frasnian; *N. mamontovi* (Yavorsky) (1955) Upper Couvinian to Lower Givetian; *N. mamontovi* var. *plana* (Yavorsky)

(1955) Couvinian; *N. conglomerata* (Lecompte) (1951) Couvinian; *N. geminata* (Lecompte) (1951) Couvinian; *N. ingens* (Ünsalander) (1951) Frasnian; *N. dipcreekensis* sp. nov. Couvinian.

*N. verrucosa* has greater complexity of laminae than other species of this genus, and in parts the laminae have almost a cellular structure (see Lecompte 1951, Pl. 10, fig. 1a), and is tentatively referred to this genus.

Flügel (1959) has indicated that *N. conglomerata* and *N. geminata* do not conform to previously described genera.

#### *Nexililamina dipcreekensis* sp. nov.

(Pl. 14, fig. 4-8)

*Actinostroma* sp. Mallett in Hill, Playford & Woods 1967, p. d.4, Pl. D2, fig. 1a, b.

**HOLOTYPE:** F.47608, from the base of the Dip Creek Limestone Member, 1 km SW. of Martin's Well, Pandanus Creek Station, North Queensland; Couvinian.

**DIAGNOSIS:** Coenostea are globular, discoidal or encrusting. Laminae are compact with irregular undulations, 0.01 to 0.08 mm thick, and can be from 0.03 to 0.6 mm apart. There are alternating zones of closely spaced single laminae, and more widely spaced laminae which may be formed of several fused laminae. There is an average of 15 to 27 laminae in 5 mm in vertical section. Dissepiments are common and may extend laterally into microlaminae. Pillars are straight and continuous, 0.07 to 0.10 mm thick. They divide or break up into a number of strands beneath complex laminae. There are 20 to 27 pillars in 5 mm in vertical section, and an average of 20 to 30 in 1 mm<sup>2</sup> in tangential section. Astrorhizae have an axial canal 0.3 mm diameter with rare radiating canals.

**DESCRIPTION:** Coenostea are globular or discoidal with a diameter from 10 to 25 cm, but two specimens are laminar and encrusting, with low irregular mame-lons 1 to 5 mm apart. Pillars are composed of compact tissue which appears to be commonly altered to the melanospheric or flocculent states. Laminae are composed of thin compact layers of tissue, 0.01 to 0.05 mm thick ( $M = 0.034$ ,  $\sigma M = 0.006$ ), which may occur separately or may be combined to form composite laminae. Composite laminae may be up to 0.08 mm thick. Where laminae are closely spaced they are simple, but where they are more widely spaced they are usually complex.

In vertical section laminae are continuous, lenticular, and have irregular undulations. The spacing of the laminae is not constant, and there may be as many as three in 1 mm, or they may be as far apart as 0.6 mm. There are alternating bands of closely and widely spaced laminae. The average number in 5 mm for each coenosteam ranges from 15 to 27 ( $M = 23.5$ ,  $\sigma M = 3.3$ ,  $\sigma m = 1.8$ ). Dissepiments are common in the galleries and may be long and straight, developing into microlaminae. Pillars are straight and regular. They have a diameter of from 0.07 to 0.10 mm ( $M = 0.089$ ,  $\sigma M = 0.006$ ), and are slightly spool-shaped in some specimens. The

number in 5 mm ranges from 20 to 27 ( $M = 23.7$ ,  $\sigma M = 1.68$ ,  $\sigma m = 1.38$ ). Pillars may split in inter-laminary spaces, particularly where laminae are widely spaced; this is well illustrated in parts of the holotype. The splitting of pillars is also more common beneath complex laminae. Astorhizal systems have an axial canal 0.3 mm diameter, and indistinct radiating canals. The laminae are upturned for a short distance around each system.

In tangential section laminae occur as thin sheets of compact tissue pierced by rare round pores 0.1 to 0.2 mm in diameter. The margins of the laminae rarely break down into a porous network, resembling crude radial arms joining pillars. Pillars are approximately circular in cross-section, and the average number in 1 mm<sup>2</sup> ranges from 20 to 32 ( $M = 26.4$ ,  $\sigma M = 2.7$ ,  $\sigma m = 1.9$ ). Dissepiments composed of compact tissue cut across galleries, and join pillars. There are 19 specimens in this collection.

**REMARKS:** The only other species of this genus which has zones of closely and widely spaced laminae is *N. conglomerata* (Lecompte). The one Broken River species has more numerous laminae in 5 mm and they are occasionally lenticular.

**RANGE:** *N. dipcreekensis* is found through the whole of the Dip Creek Limestone Member (*derivatio nominis*) on the Martin's Well traverse, 1 km SW. of Martin's Well (L.2977, L.2979, L.2513, L.2981); and in the lower part of the Chinaman Creek Limestone Member, up to 140 m W. of the base of the Member on Chinaman Creek South (L.2509).

## ACKNOWLEDGMENTS

This work is part of a study of the whole stromatoporoid fauna of the Broken River Formation on Pandanus Creek Station, done under the supervision of Professor D. Hill, and I would like to thank her for her assistance and encouragement. Dr. J. Jell made specimens available and also indicated suitable localities for making collections.

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## APPENDIX:

## DESCRIPTIONS OF COLLECTION LOCALITIES

### DIP CREEK LIMESTONE MEMBER

MARTIN'S WELL TRAVERSE: SW. across the limestone from a point on the base of the limestone, 1 km SW. of Martin's Well, Pandanus Creek Station, with the distances of localities in a direction SW. from the base of the limestone.

- L.2977—0.50 m (Couvinian)
- L.2978—150 m (Couvinian)
- L.2979—300 m (Couvinian)
- L.2980—500 m (Couvinian)
- L.2981—800 m (Couvinian)
- L.2982—900 m (Couvinian)
- L.2513—locality not on traverse, approximately

400 m SW. of the base of the limestone, 0·8 km SW. of Martin's Well. (Couvinian)

L.2499—Right-hand tributary of Pandanus Creek, 2·4 km upstream from the junction of Dip Creek and Pandanus Creek, 6 km E. of the homestead, Pandanus Creek Station. (Couvinian)

L.2984—Ridge, 165 m NE. of creek crossing, 6·8 km S. of the Pandanus Creek Homestead on the Pandanus Creek-Wandovale Road. (Couvinian or Lower Givetian)

#### ISOLATED RUDITES

L.2968—Wandovale-Pandanus Creek Road, 2·8 km S. of Pandanus Creek Homestead. (Couvinian)

#### CHINAMAN CREEK LIMESTONE MEMBER

TRAVERSE UP CHINAMAN CREEK SOUTH: Distances are measured W. from the base of the limestone member.

L.2509—140 m (Couvinian)

L.2510—500 m (Givetian)

L.2976—1,000 m (Givetian)



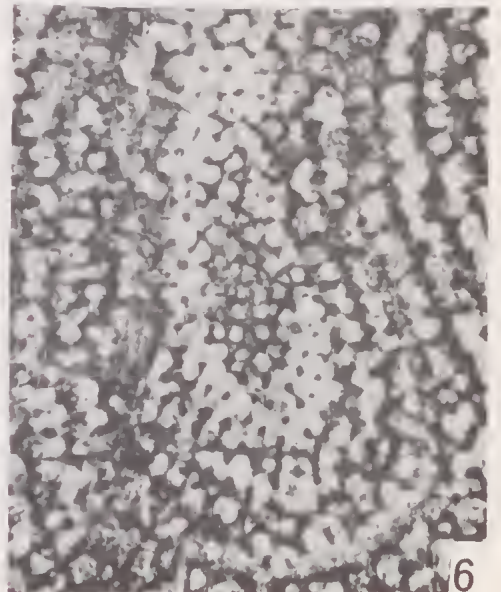
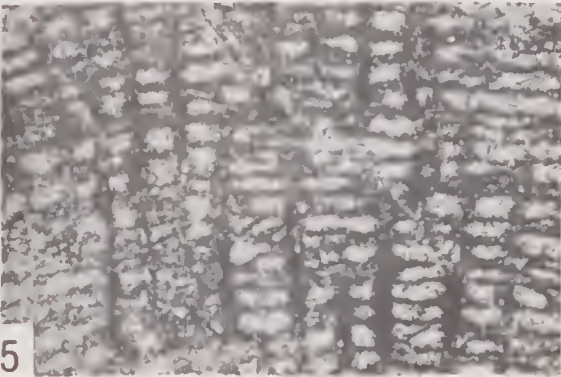
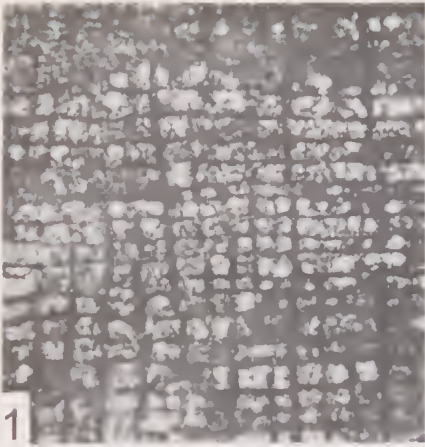
## DESCRIPTION OF PLATES

## PLATE 13

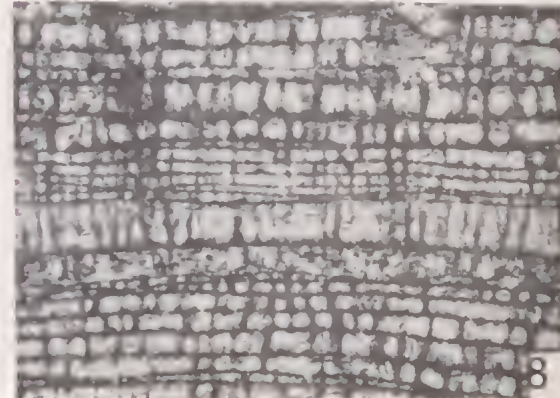
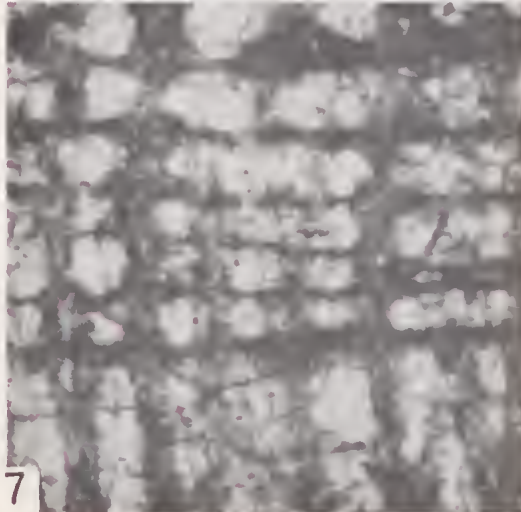
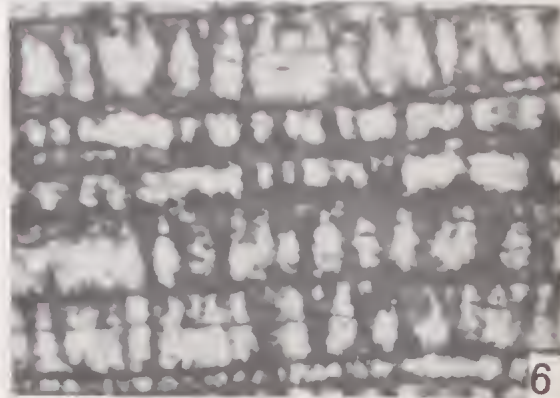
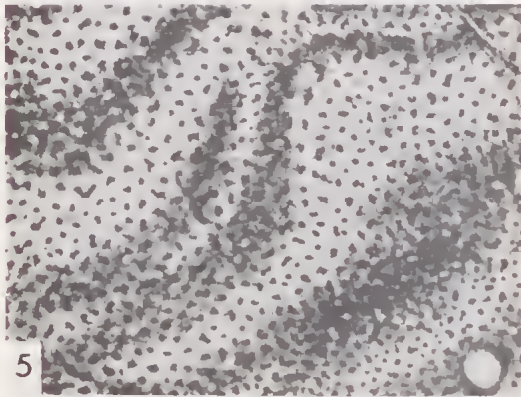
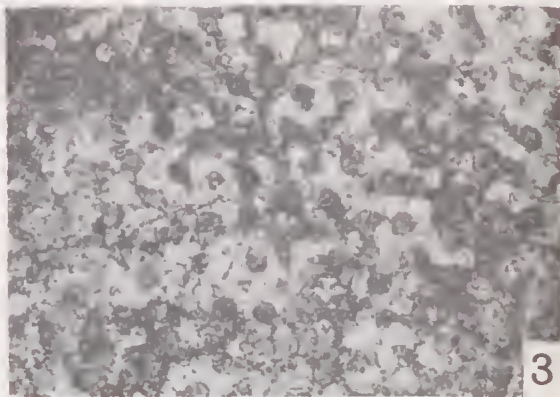
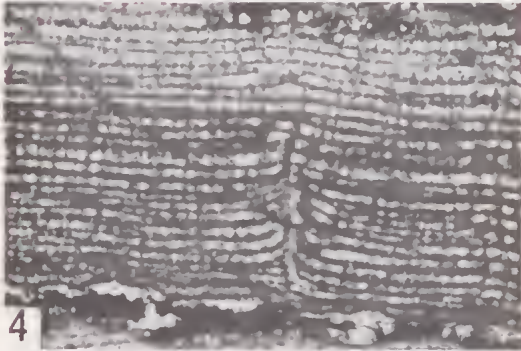
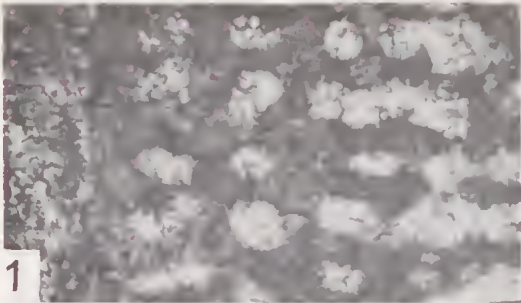
- FIG. 1—*Actinostroma papillosum* (Bargatzky), vertical section,  $\times 10$ . F.47635 from the top of the Chinaman Creek Limestone Member on Chinaman Creek South, Pandanus Creek Station (Givetian).
- FIG. 2—*Actinostroma clathratum* Nicholson, vertical section,  $\times 10$ . F.47591 from 150 m SW. of the base of the Dip Creek Limestone Member, 1 km SW. of Martin's Well, Pandanus Creek Station (Couvinian).
- FIG. 3—*Actinostroma dehornae* Lecompte, tangential section,  $\times 10$ . F.47874 from 500 m W. of the base of the Chinaman Creek Limestone Member, Chinaman Creek South, Pandanus Creek Station (Givetian).
- FIG. 4—*Actinostroma clathratum* Nicholson, tangential section,  $\times 10$ . F.47982 from Chinaman Creek Limestone Member on Chinaman Creek South, Pandanus Creek Station.
- FIG. 5—*Actinostroma dehornae* Lecompte, vertical section,  $\times 10$ . F.47874.
- FIG. 6, 7—*Actinostroma stellulatum* Nicholson. F.42688B from Dip Creek Limestone Member on Dip Creek, 2.4 km upstream from the junction of Dip Creek and Pandanus Creek, Pandanus Creek Station (Couvinian). 6. tangential section,  $\times 20$ . 7. vertical section,  $\times 10$ .

## PLATE 14

- FIG. 1-3—*Actinostroma steloges* sp. nov. Holotype, F. 47755, from Dip Creek Limestone Member of the Broken River Formation, 800 m SW. of the base of the Member, 1 km SW. of Martin's Well, Pandanus Creek Station. 1. vertical section,  $\times 20$ , showing coarse skeletal elements with impersistent laminae. 2. vertical section,  $\times 10$ , showing the coarse continuous pillars. Alteration has affected the specimen in the central part of the figure. 3. tangential section,  $\times 10$ , showing radial arms joining pillars and some pillars with dark lumen.
- FIG. 4-8—*Nexililamina dipcreekensis* sp. nov. 4. vertical section,  $\times 10$ , F.47741, from the Dip Creek Limestone Member, 500 m SW. of its base, 1 km SW. of Martin's Well, Pandanus Creek Station; showing a typical astrorhiza. 5. tangential section,  $\times 10$ , Holotype, F.47608, from the base of the Dip Creek Limestone Member 1 km SW. of Martin's Well, Pandanus Creek Station; showing laminae as porous sheets of compact tissue with no radial arms joining pillars. 6. vertical section,  $\times 20$ , Holotype, showing a part of the coenosteum where pillars split beneath laminae, and a complex lamina is formed by the fusion of two laminae. 7. vertical section,  $\times 50$ , Holotype, showing fine simple laminae with thicker pillars. The tissue of the pillars has light spots which are not considered to be vacuoles, but imperfections in preservation. Many specimens are excellently preserved and the tissue is in the main compact. 8. vertical section,  $\times 10$ , Holotype. This section shows simple and complex laminae, closely and distantly spaced. The lower part of the section is oblique to the pillars and gives a false impression that pillars are short and confined to a single interlaminary space.









# FOSSIL DINOFLAGELLATE CYSTS FROM LAKE GNOTUK, VICTORIA, AUSTRALIA

By REX HARLAND\*

**ABSTRACT:** Seven previously undescribed fossil dinoflagellate cysts are reported from Lake Gnotuk, a highly saline volcanic crater lake in Victoria, Australia. The cysts are discussed in the light of recent Quaternary dinoflagellate studies; and in particular with regard to the problems of classification. A possible future solution is introduced whereby all Quaternary fossil cysts are classified in a natural scheme whilst older material is classified morphologically, with natural affinities stated where known or reasonably assured.

## INTRODUCTION

In recent years the study of fossil Quaternary dinoflagellate cysts has greatly expanded. At present these palynomorphs are being treated as morphological entities as in Harland (1968), Harland and Downie (1969), Harland and Sarjeant (1970) and Downie and Singh (1969); and as complete natural entities by Wall and Dale (1968a, b) and Evitt and Wall (1968). It is becoming clear that a comprehensive system of taxonomy and classification is necessary to reconcile these two different approaches. The present paper, in describing a Holocene (Flandrian) assemblage of fossil dinoflagellate cysts, attempts to highlight the problems involved and to offer a tentative future solution.

The assemblage was obtained from Lake Gnotuk, a small volcanic crater lake situated close to the town of Gnotuk in south-west Victoria, Australia. Gnotuk lies about 8 miles to the north-east of Cobrico. The geographical setting may be seen in Fig. 1. Lake Gnotuk and Cobrico Swamp, the latter described by Harland and Sarjeant (1970), are both developed on Tertiary basalt lava flows. The sediments studied are, however, of Holocene (Flandrian) age. The extent of contamination in the geological environment is therefore slight, and indeed no recognizable reworked material was seen. The sample described in this paper was taken from surface mud in Lake Gnotuk under a water depth of 60-65 ft. Dr. D. M. Churchill, who collected the sample, also noted the presence of large number of living dinoflagellates in the highly saline lake water. The chemistry of the water is as follows:

TABLE 1

pH	8.60
Salinity	53.50 g/l
Na <sup>+</sup>	16.70 "
K <sup>+</sup>	0.62 "
Mg <sup>++</sup>	2.17 "
Ca <sup>++</sup>	0.18 "
Cl <sup>-</sup>	33.00 "
SO <sub>4</sub> <sup>-</sup>	0.00 "
HCO <sub>3</sub> <sup>-</sup> and CO <sub>3</sub> <sup>-</sup>	0.014 "

*Data from Bayly and Williams 1966.*

It is unfortunate that only one slide was available to the author for study. This has been designated L.G.V./001 and is housed in the Palynological Collection of the Department of Geology, University of Alberta, Edmonton, Canada. The available material does not facilitate the study of large populations of cysts but the palynomorphs present are of such interest that they are herein described. The systematic positions of these cysts is purposely left 'loose' for reasons explained later.

## TAXONOMY AND CLASSIFICATION

Lately research workers have become increasingly concerned with the taxonomy and classification of dinoflagellate cysts. Sarjeant and Downie (1966) reviewed the state of the various classifications to date and erected a purely morphological scheme for fossil dinoflagellate cysts. Wall and Dale (1968a), studying the theca-cyst relationship in many modern dinoflagellate taxa, suggested several new procedures that workers should adopt to ensure a comprehensive classification for both modern and fossil dinoflagellates. These procedures are quoted below:

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1. Modern dinoflagellate taxa must be redefined to attribute greater taxonomic importance to the cyst phase and should be restricted to include only specifically defined cyst morphotypes. Polyphyletic modern genera or species should be subdivided at some level. Fossil and dissociated living cysts then could be assigned to these redefined taxa on the basis of features of cyst morphology as one minimum requirement.

2. Fossil and living dinoflagellates which are synonymous according to cyst or thecal morphology must adopt a single epithet.

3. Extinct dinoflagellates must be allocated to taxa on the basis of their archeopyle plate equivalence, reflected tabulation, and other characters whose taxo-

nomie value can be affirmed by reference to the holomorph, that is, the living dinoflagellate. The relative height of ornamentation upon a cyst would be of minor importance in this scheme.

Norris and McAndrew (1970), describing a postglacial freshwater cyst assemblage, criticize the scheme of Wall and Dale (*op. cit.*) and conclude that separate classifications are needed for cysts and thecae. At the moment then we have a morphological classification for fossil cysts, a biological one for modern thecae and various suggestions to erect a new comprehensive classification for modern dinoflagellates to include fossil cysts. A split between workers is developing: those

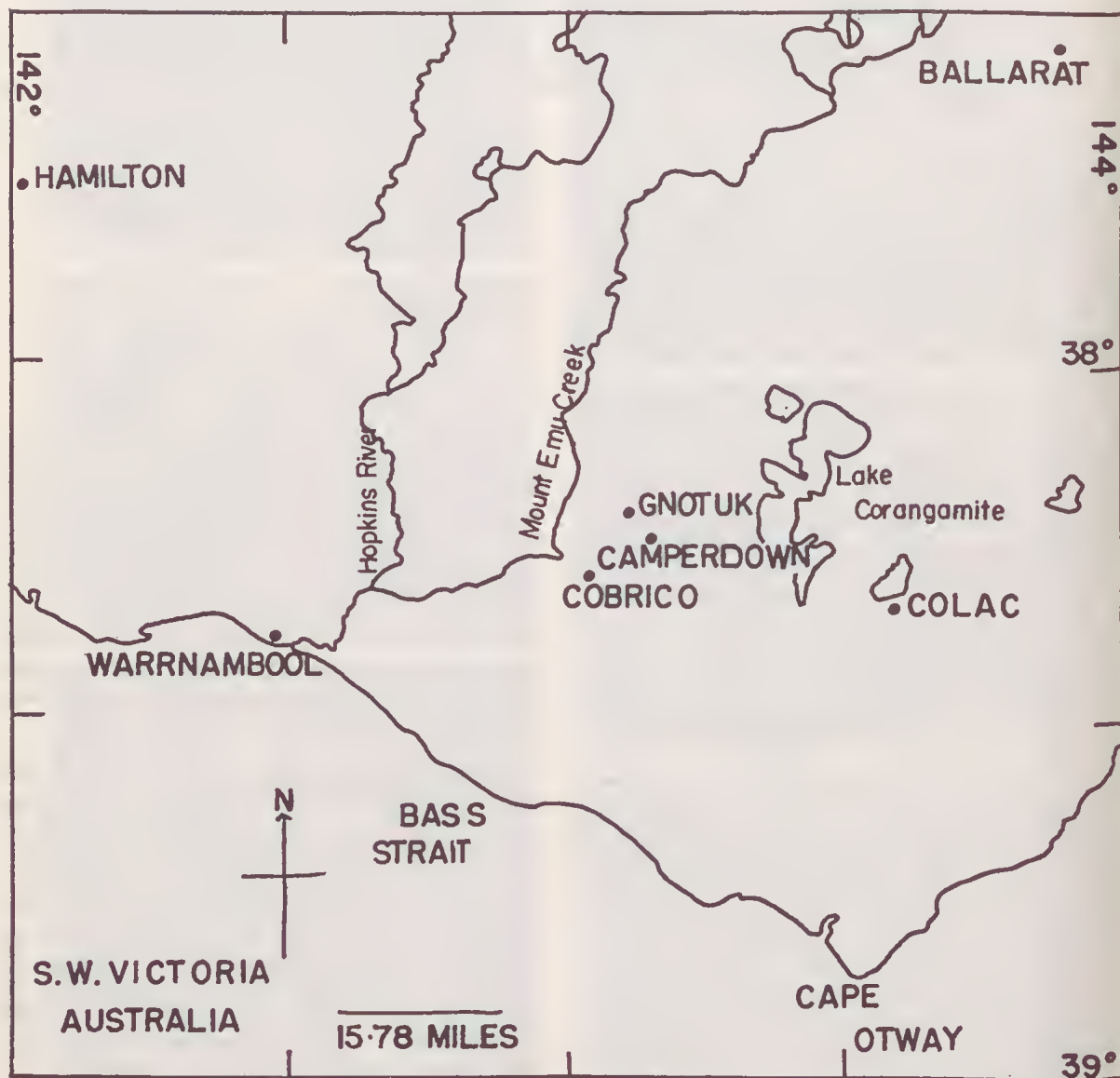


FIG. 1.—Sketch Map of S.W. Victoria, Australia, showing the geographical location of Gnotuk.



who wish to see a separate classification for cysts and thecae and those who favour the new comprehensive approach. The present author would like to offer a 'compromise', at this stage, to prevent or alleviate the schism.

Norris (pers. comm.) has pointed out that morphological data need to be organized into conceptually meaningful units before taxonomy can be attempted. Similarly this must be done for any form of data to be used taxonomically. In dinoflagellate taxonomy there is still much argument at this fundamental level. Wall and Dale (1968a) contend that tabulation and archeopyle development are taxonomically stable characters and can be used without reserve in erecting a classification. Norris (pers. comm.) suggests that this is as yet unclear. Certainly in the case of the freshwater cysts studied by Norris and McAndrew, those of Harland and Sarjeant (1970), and those presently under consideration, the author would be inclined to support Norris's view. The relative importance of the degree of cyst condensation is another disputed taxonomic criterion. Sarjeant and Downie (1966) believe this to be of utmost importance in their classificatory scheme, whilst Wall and Dale (1968a) dismiss the criterion on the ground that 'spine length can be subject to considerable intraspecific variation'. It would seem then that there is some semantic confusion by what is meant by cyst condensation and what by spine length, and the difference between 'spine' and 'process'. The natural significance of all morphological attributes needs to be properly evaluated in order to select meaningful criteria for an ideal classification embracing both fossil and extant forms. The principles of numerical taxonomy (Rowell 1967) could well be a valuable addition to the 'classical' approach.

The author feels that at present a compromise is necessary. It is therefore suggested that all Quaternary fossil dinoflagellate cysts should be classified under a natural scheme, as it is reasonable to surmise that in the future the majority of Quaternary fossil cysts will be assigned to their parent thecae, in the same way that Quaternary pollen and spores are attributed to their parent plants. Physiological, cytological and genetical data must ultimately be included in such a taxonomy, and Norris and McAndrew (1970) suggest that a particularly fruitful line of research might be the detailed study of the process of cyst formation. The only realistic way to classify pre-Quaternary fossil material is on purely morphological grounds, taking into account the importance of the various morphological parameters. Ultimately an amalgamation of these two systems may be possible, especially if the cyto-

logical, physiological and genetical data are found to be relatively unimportant in the total taxonomic concept. It is the author's view that current knowledge is too meagre to allow the erection of a comprehensive classification at the present time.

The present assemblage does not fit into any of the schemes discussed, as none of its members can be assigned to parent thecae owing to the lack of knowledge of theca-cyst relationships in 'freshwater' dinoflagellates. In some cases it is considered reasonable to assign cysts to modern genera where the evidence allows, e.g. *Peridinium* and *Gonyaulax*, but in other instances the author had no alternative but to assign the cysts to a morphologically defined genus, e.g. *Aquadulcum*. Clearly this is not a very satisfactory situation; it points to the scope of future work necessary before a consistent taxonomic approach can be adopted.

## SYSTEMATICS

### Class DINOPHYCEAE Pascher

### Order PERIDINIALES Lindemann

### Family PERIDINIACEAE Lindemann

### Genus *Peridinium* Ehrenberg 1830

Type Species *P. cinctum* (O. F. Muller) Ehrenberg 1830; OD(M).

### *Peridinium* sp. A

(Pl. 15, fig. 1-2; Fig. 2-5)

DESCRIPTION: Proximate cysts, spherican to ovoidal in shape. Compressed forms appear somewhat rectangular in outline. Two cyst walls are commonly closely adpressed except toward the apical region where the periphragm alone constructs a short apical horn. The resultant pericoel is usually very conspicuous. Cyst wall is 1-2  $\mu$  in thickness. Ornamentation is very variable, most commonly consisting of fine to coarse granules irregularly arranged on the cyst. These granules, constructed of periphragm, are often elongate producing a vermiculate appearance. One specimen had vermiculae parallel to the longitudinal axis of the cyst. Tabulation is typical for the genus, i.e. 4', 7'', 6c, 6'', 1p, 2'''. The plate areas are defined by a single or a double raised suture, the latter possibly reflecting small growth areas on the mature theca. The apical series consists of four plates, plate 1' being elongate and apparently an extension of the sulcal groove. The pre-cingular series consists of seven rectangular plates, plate 4'' being particularly conspicuous. The cingulum consists of six elongate-rectangular plates, and is 5-6  $\mu$  wide. The plates lie in a shallow groove and form a laevo-rotatory spiral. The sulcus is usually conspicuous and extends up to three-quarters of the length of the hypotract and only a short distance on to the epitract. The longitudinal sulcal and the posterior sulcal plates are usually well defined; in some specimens additional plates are evident. A tentative composite tabulation for these cysts is shown in Fig. 2-5. The post-cingular plate series



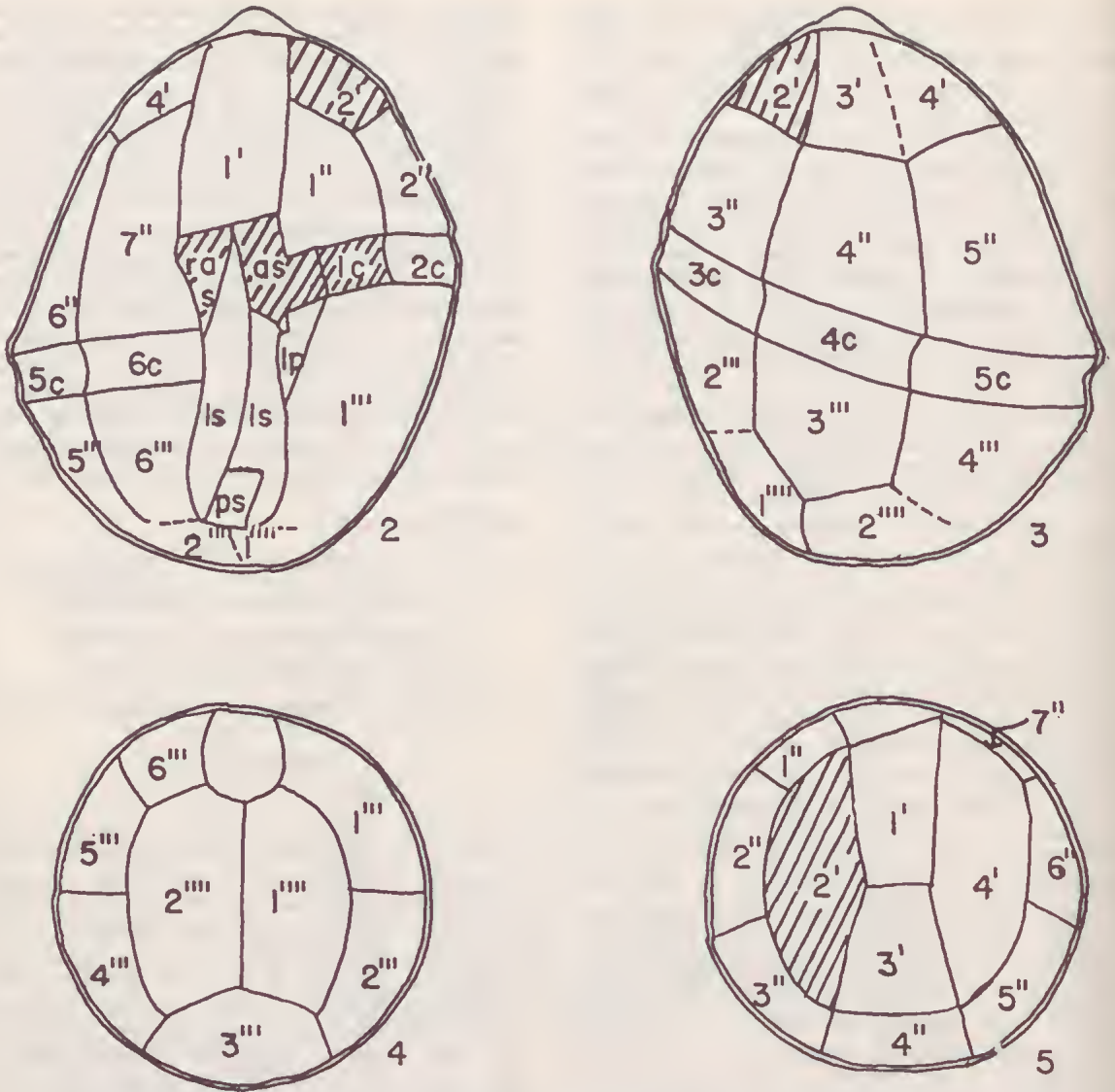


FIG. 2-5—*Peridinium* sp. A, Ventral view showing both types of possible archeopyle. *ls* longitudinal sulcal plate, *ps* posterior sulcal plate, *as* anterior sulcal plate, *ras* right accessory sulcal plate.  $\times 1,500$ . (3) *Peridinium* sp. A, Dorsal view.  $\times 1,500$ . (4) *Peridinium* sp. A, Antapical view.  $\times 1,500$ . (5) *Peridinium* sp. A, Apical view.  $\times 1,500$ .

consists of six plates of which pentagonal plate 3''' is the most conspicuous. A small triangular posterior intercalary plate is also evident in some specimens. This plate is so variable in size from specimen to specimen that it may in fact be part of the sulcal plates. The tabulation is completed by two large antapical plates. Two possible archeopyle developments occur: in one an archeopyle was formed by loss of a single apical plate, i.e. 2', that could be termed A in the terminology of Evitt (1967); and a second resulted from the loss of plate 1c and sulcal plates as indicated in Fig. 2. Evitt (op. cit.) and Norris and McAndrew (1970) all indicate the com-

plexities of archeopyle formation in *Peridinium* so that it is no surprise that these specimens do not fit into the usual modes of archeopyle formation. It may be, however, that these ruptures are entirely accidental.

**DIMENSIONS:** Length 52 (54.2) 59  $\mu$ ; breadth 46 (50.8) 54  $\mu$ . Five specimens were measured. The figure in parenthesis is the arithmetic mean of the data.

**REMARKS:** The cysts described above are assignable to the genus *Peridinium* by virtue of their tabulation, but do not compare closely to any of the fossil cysts described to date. The form differs from those de-

scribed by Evitt and Wall (1968) and Wall and Dale (1968a) in the lack of antapical horns. The two possible types of archeopyle point to the possibility that at least two species of *Peridinium* may be represented in this taxon. Certainly it makes no sense to erect a new genus distinct from *Peridinium* based on the differences of archeopyle structure. No definitive proof is available to the affinity of these cysts to a motile theca but a loose assignment to *Peridinium* appears justified.

? *Peridinium* sp. B

(Pl. 15, fig. 3-4; Fig. 6-9)

DESCRIPTION: Proximate cyst, ovoidal to peridinoid

in shape. Cyst made up of two walls closely adpressed except at the apex where the periphragm makes up an apical horn, resulting in an apical pericoel. The cyst wall is  $1-2\ \mu$  thick. Ornamentation consists of granules, up to  $0.5\ \mu$  in diameter, uniformly arranged on plate areas. Tabulation is  $4'$ , ?  $4''$ ,  $6c$ ,  $6'''$ ,  $2''''$ . Plate areas are delimited by single and double raised sutures. The apical series consists of four plates of which  $1'$  is an elongate hexagonal plate and  $3'$  is pentagonal. The pre-cingular series appears to comprise only four large plates. The cingulum lies in a shallow groove and takes the form of a laevo-rotatory spiral. It consists of five elongate rectangular plates ( $4c$ ). The cingulum is  $3\ \mu$

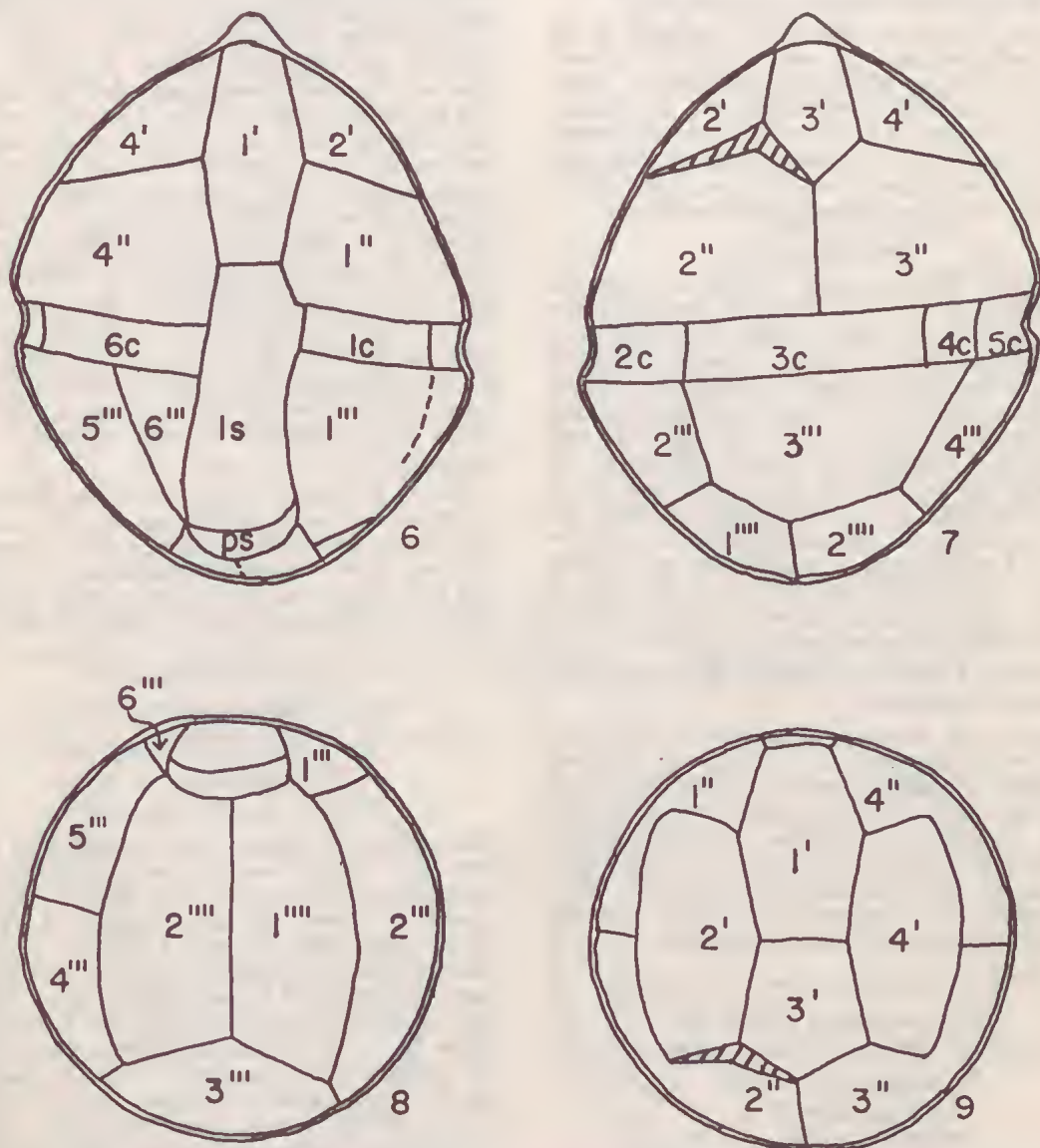


FIG. 6-9— ? *Peridinium* sp. B, Ventral view. *ls* longitudinal sulcal plate, *ps* posterior sulcal plate.  $\times 1,500$ . (7) ? *Peridinium* sp. B, Dorsal view showing the archeopyle.  $\times 1,500$ . (8) ? *Peridinium* sp. B, Antapical view.  $\times 1,500$ . (9) ? *Peridinium* sp. B, Apical view.  $\times 1,500$ .



in width and has a displacement equal to half the cingulum width. The sulcus is well developed, lying mainly on the hypotract and extending only one-fifth on to the epitract. It consists of a single large longitudinal sulcal plate and a small posterior sulcal plate. The post-cingular plate series comprises six plates, plate 3''' large and pentagonal, plate 6''' small and triangular. The antapical series consists of two large square plates. The archeopyle appears as a split between plates 2' and 3' and 2'' on the epitract; there appears to be no plate loss. This again may be accidental, however. A tentative composite tabulation is diagrammatically illustrated in Fig. 6-9.

**DIMENSIONS:** Length (53 (54) 55  $\mu$ ; breadth 48 (52) 56  $\mu$ . Two specimens were seen and measured.

**REMARKS:** This fossil appears best assigned to the genus *Peridinium* although some doubt is expressed due to the presence of only four pre-cingular plates. It differs from *P. sp. A* in lacking two pre-cingular plates, in the lack of accessory plates in the ventral area, and finally in the possible mode of archeopyle formation. Unfortunately only two specimens of this interesting form were observed in the assemblage.

#### *Peridinium sp. C*

**DESCRIPTION:** Proximate cyst, ovoidal in shape, the epitract being more conical than the hypotract. The cyst consists of two walls closely adpressed except where the periphragm constructs a prominent apical horn. A large apical pericoel is also present. Ornamentation consists of two types, microgranules and small sutural spines that stand 2-3  $\mu$  above the cyst surface. The tabulation is obscure but clearly of *Peridinium*-type in that the large pentagonal 3''' is conspicuous. Plate areas are delimited by single and double raised sutures. The cingulum lies in a shallow groove 7  $\mu$  wide, and has a displacement equal to half its width. The sulcus is similar to that of *P. sp. A*, although the multiplicity of sulcal plates was not seen. No archeopyle was observed.

**DIMENSIONS:** Length 59  $\mu$ ; breadth 50  $\mu$ . One specimen seen and measured.

**REMARKS:** This specimen is assigned to the genus *Peridinium* on the evidence of tabulation. However, considerable intraspecific variation in thecal and cyst morphology is known within such genera as *Peridinium*, *Gonyaulax*, and *Ceratium*. It is probable that the specimen is linked with *P. sp. A* via such variation, but this cannot be demonstrated from the available material. Unfortunately the single specimen observed could not be illustrated adequately.

#### Family GONYAULACACEAE Lindemann

##### Genus *Gonyaulax* Diesing 1866

Type Species *G. spinifera* (Claparède and Lachmann) Diesing 1866; OD(M).

##### *Gonyaulax sp. A*

(Pl. 15, fig. 5-9; Fig. 10-13)

**DESCRIPTION:** Proximate cysts, spherical to ovoidal, may appear rectangular if compressed. Two cyst walls are present, closely adpressed except where the peri-

phragm makes up an apical horn with the development of a small apical pericoel. The cyst wall is 1-2  $\mu$  thick. Ornamentation takes the form of granules, often large and elongate in plan and arranged uniformly on the periphragm. A true vermiculate appearance was not, however, seen in any specimen here attributed to the genus. Tabulation is 4', 6'', 6c, 6''', 1'''. The plate areas are defined by single or double raised sutures. The apical series consists of four plates of which 1' is elongate and appears to form an extension to the sulcus, and plate 3' which is short and trapezoidal. The pre-cingular plate series of six plates has as its most conspicuous plate a large hexagonal 4''. The cingulum lies in a groove and consists of six elongate-rectangular plates; it bisects the cyst and forms a laevo-rotatory spiral. Displacement is equal to one width of the cingulum (9  $\mu$ ). The sulcus is conspicuous and commonly consists of a single sulcal plate with the possible addition of a posterior, left and left accessory sulcal plates. The sulcus extends a short distance on to the epitract and one-quarter of the way on to the hypotract. The post-cingular plate series consists of six rectangular plates; the single antapical plate is square. A tentative tabulation is illustrated in Fig. 10-13. One specimen showed a possible archeopyle development, by loss of plate 5''.

**DIMENSIONS:** Length 52 (55.4) 59  $\mu$ ; breadth 48 (52.6) 58  $\mu$ . Five specimens were seen and measured.

**REMARKS:** All five specimens seen are assignable to the genus *Gonyaulax*, but are not comparable to any fossil cyst described to date. A study of the motile thecae of Lake Gnotuk is obviously essential.

#### ADDENDUM

Due to the paucity of material the descriptions and text-figures of the *Peridinium* spp. and *Gonyaulax* sp. are intended as a general indication of the morphology of these cysts. Certain inconsistencies are apparent and it is hoped that with future research their morphology and taxonomic position will become clearer.

#### INCERTAE FAMILIAE

##### Genus *Diplopeltopsis* Pavillard 1913

Type Species *D. minor* (Paulsen) Pavillard 1913; OD.

##### *Diplopeltopsis sp. A*

(Pl. 15, fig. 10-11; Fig. 14-15)

**DESCRIPTION:** Proximate cyst, spherical, with a small horn at the apical end. Cyst wall composed of two layers closely adpressed even at the apex. The ornamentation consists of small granules in a dense arrangement giving the cyst a scabrate appearance. The tabulation is indistinct and where seen the plate areas are delineated by narrow faint raised ridges; of the tabulation figured by Wall and Dale (1968a) plates 2a, 3'', 4'', 5'', and 6'' could be faintly seen on this specimen. The cingulum, 4  $\mu$  wide, is conspicuous on the dorsal region of the cyst lying in a shallow groove. On the ventral surface the exact position of the cingulum is unclear. A faint sulcal area, lying entirely on the hypotract, may also be seen. The archeopyle is conspicuous but due to the lack of cingular detail on the ventral surface its exact position



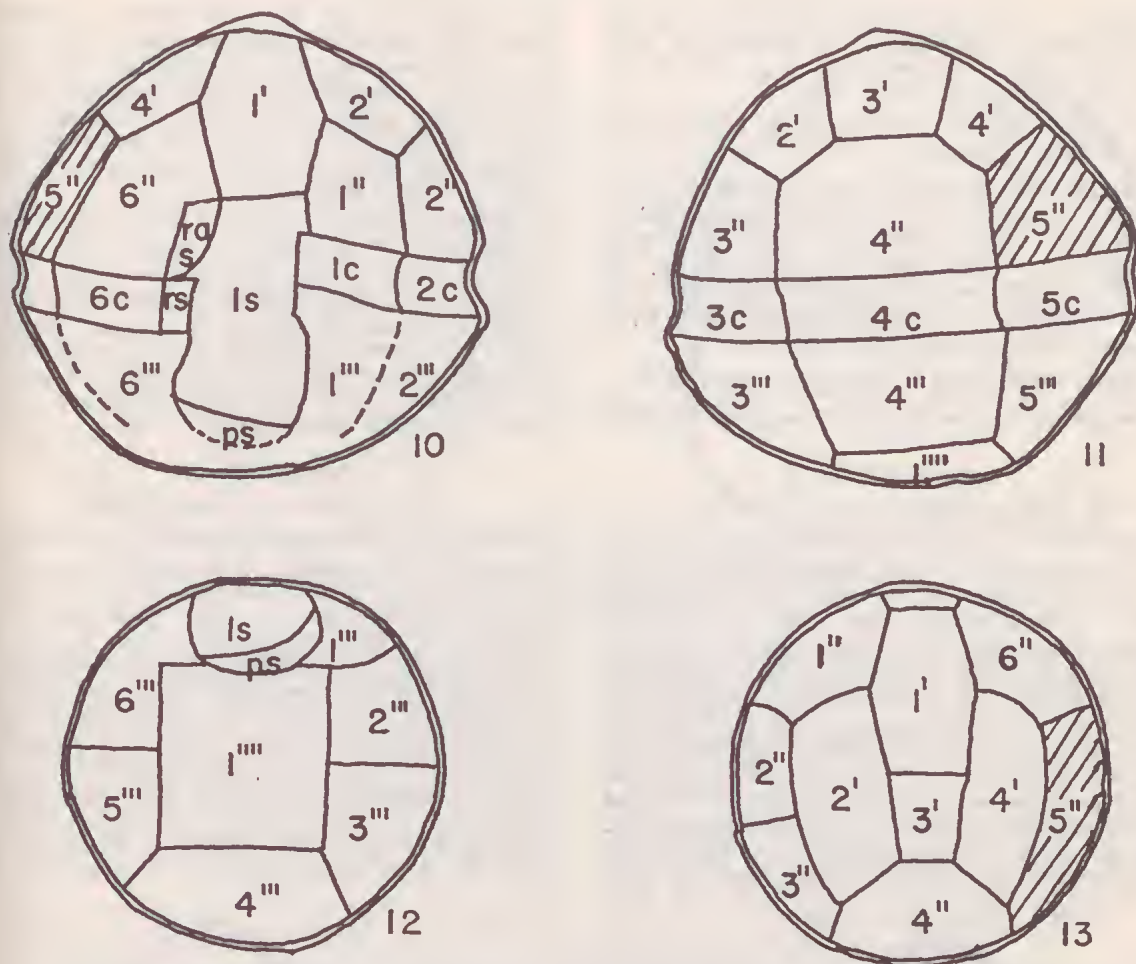


FIG. 10-13—*Gonyaulax* sp. A, Ventral view showing the archeopyle. *ls* longitudinal sulcal plate, *ps* posterior sulcal plate, *ras* right accessory sulcal plate, *rs* right sulcal plate.  $\times 1,000$ . (11) *Gonyaulax* sp. A, Dorsal view showing the archeopyle.  $\times 1,000$ . (12) *Gonyaulax* sp. A, Antapical view.  $\times 1,000$ . (13) *Gonyaulax* sp. A, Apical view.  $\times 1,000$ .

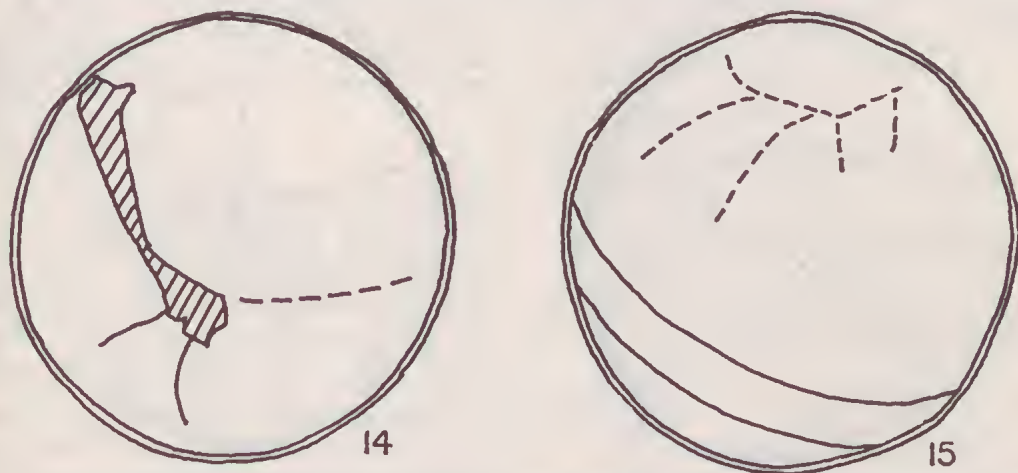


FIG. 14-15—*Diplopeltopsis* sp. A, Ventral view showing the archeopyle.  $\times 1,500$ . (15) *Diplopeltopsis* sp. A, Dorsal view.  $\times 1,500$ .

is difficult to determine. It is thought, however, to be a split between the cingular and pre-cingular plate areas but without the loss of any plates. This occurs in the area of plates 6'' and 7''.

**DIMENSIONS:** Length 45  $\mu$ ; breadth 45  $\mu$ . One specimen seen and measured.

**REMARKS:** This specimen compares favourably with *Diplopetopsis minor* (Paulsen) Pavillard as figured by Wall and Dale (1968a). An obvious difference, however, is the lack of a clear tabulation on the specimen under discussion. As Wall and Dale (op. cit.) have stated these cysts are scarcely known from the fossil record.

Genus *Aquadulcum* Harland and Sarjeant 1970

Type Species *A. serpens* Harland and Sarjeant 1970; OD.

? *Aquadulcum* sp. A

(Pl. 15, fig. 12, Plate 16, fig. 1, 8; Fig. 16-17)

**DESCRIPTION:** Proximate cyst, subspherical in shape. Cyst composed of two walls, closely adpressed except at the apex where a slight apical horn is developed with a correspondingly small apical pericoel. The epitract is markedly more conical than the hypotract and these two arcas are ornamented with granules and vermiculae. The vermiculae are clearly elongate parallel to the longitudinal axis of the cyst. There are also thicker regions in the cyst wall, apparently where only the endophragm has thickened. No corresponding structure is seen on the periphragm, and no tabulation or pattern could be discerned in their arrangement. The cingulum is a broad groove, 7-8  $\mu$  wide, and is delimited by a double raised suture. It is the usual

laevo-rotatory helicoid. There are possibly six cingular plates. The sulcus is a large structure, lying in a groove and consisting of two plates, an anterior sulcal plate and a posterior sulcal plate. It extends for a short distance on to the epitract but is conspicuously present on the hypotract. A possible triangular pre-cingular plate is seen in 1'' position. Archeopyle develops by the loss of plate 1''.

**DIMENSIONS:** Length 52 (53.5) 55  $\mu$ ; breadth 45 (47.5) 50  $\mu$ . Two specimens were seen and measured.

**REMARKS:** This cyst may reasonably be attributed to *Aquadulcum* although three of its features, granular ornament on cingulum and sulcus, an apical pericoel and a pre-cingular archeopyle, do not accord with the genus. It may prove necessary, with availability of further material, to extend the diagnosis of *Aquadulcum* so as to include this cyst.

? *Aquadulcum* sp. B

(Pl. 16, fig. 2-7, 9-11; Fig. 18-19)

**DESCRIPTION:** Proximate cyst, spherical to ovoidal in shape, cyst wall consists of two closely adpressed layers except at the apex where an apical horn, spine and apical pericoel are developed. This varies with specimen; in some it is very conspicuous whereas in others it is only a small development. In one specimen the apical horn was surmounted by a delicate spine, as illustrated in Pl. 16, fig. 11. Ornamentation varies from microgranulate through coarsely granulate to vermiculate. The cingulum lies in a shallow groove which is delimited by a single or double raised suture; it is 4-5  $\mu$  wide and forms a laevo-rotatory helicoid. It has an ornament similar to the rest of the cyst. The sulcus is conspicuous and is confined to the

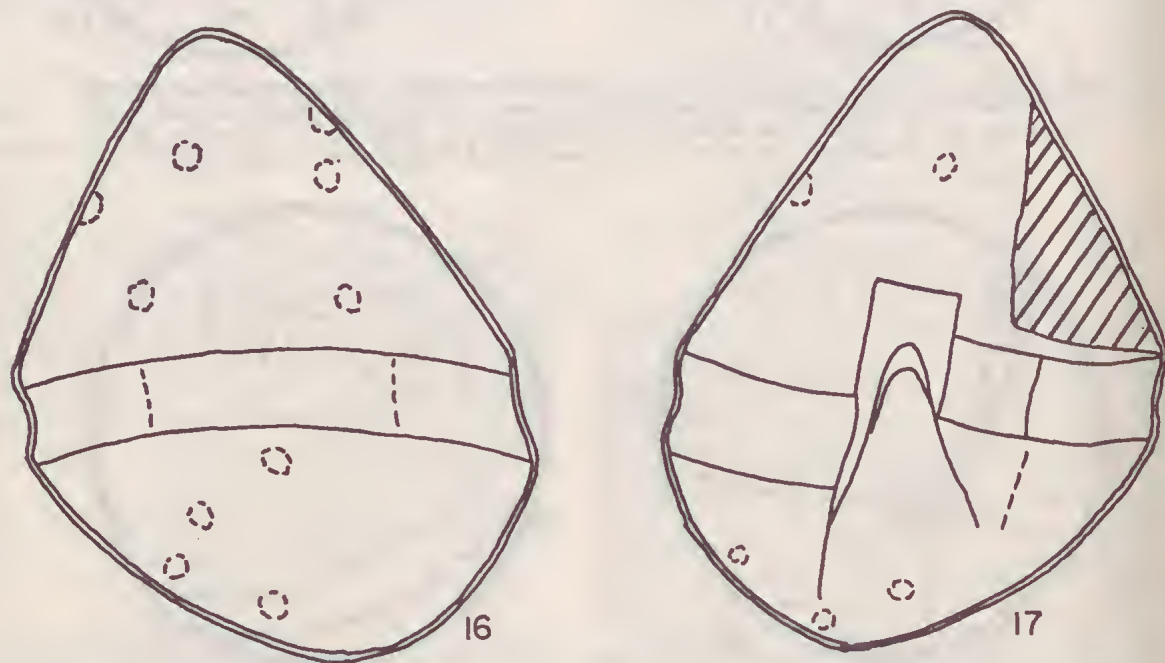


FIG. 16-17—? *Aquadulcum* sp. A, Dorsal view.  $\times 1,500$ . (17) ? *Aquadulcum* sp. A, Ventral view showing the archeopyle.  $\times 1,500$ .

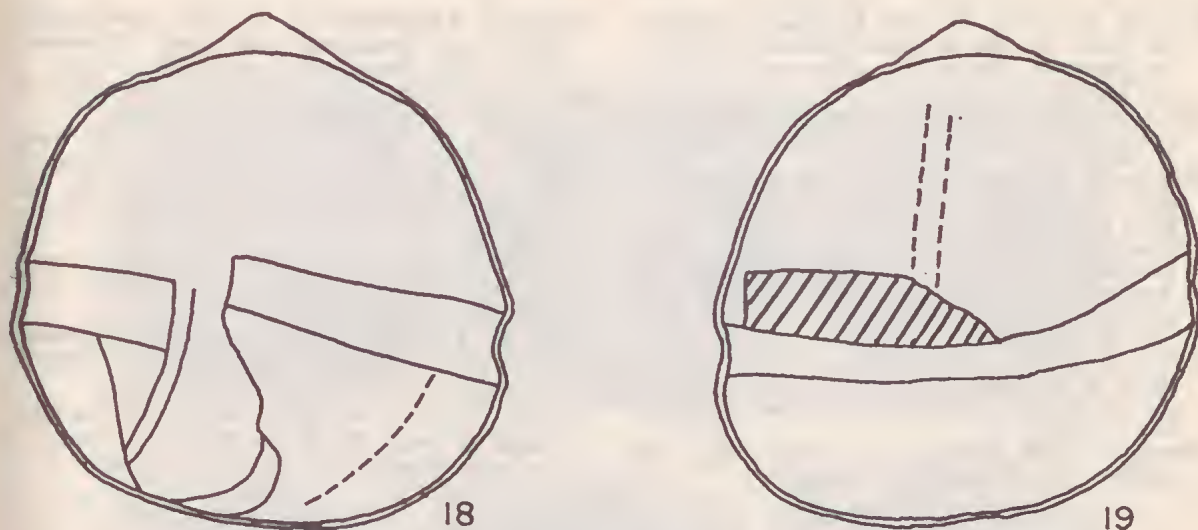


FIG. 18-19—? *Aquadulcum* sp. B, Ventral view.  $\times 1,200$ . (19) ? *Aquadulcum* sp. B, Dorsal view showing the archeopyle.  $\times 1,200$ .

hypotract. It is made up of a longitudinal suleal plate, a posterior suleal plate and a right suleal plate. One or two plate areas, defined by ornament differences, occur on the cyst. Two plates in the pre-ingular plate series are delimited by a groove extending from the 'archeopyle'; and two others, possibly 1''' and 6'', are defined by a raised suture. The archeopyle, illustrated in Pl. 16, fig. 10, appears to develop by partial loss of one of the pre-ingular plate series, possibly plates 2'' or 3''.

**DIMENSIONS:** Length 51 (53.3) 57  $\mu$ ; breadth 46 (46.6) 50  $\mu$ . Six specimens measured, the total available material.

**REMARKS:** These specimens, like those of the preceding category, are probably assignable to the genus *Aquadulcum* but certain differences are apparent in the ornamentation and overall cyst morphology. The present cysts differ from those of ? *A.* sp. A in not having the elements of ornament aligned parallel to the longitudinal axis of the cyst, in archeopyle structure, and in lacking conical epitract and endophragmal thickenings.

## CONCLUSIONS

A new assemblage of seven previously unknown fossil dinoflagellate cysts has been described from Lake Gnotuk, Victoria, Australia. Taxonomically these proved to be a little difficult to handle because of the lack of previous research. In a discussion of the taxonomic problems associated with dinoflagellate cysts, therefore, the author suggests that an arbitrary boundary be erected between Quaternary forms and all older material as is generally practised with pollen and spores. Quaternary dinoflagellates would accordingly be classified in a natural scheme where possible, whilst all older material would be morphologically classified

but with a clear knowledge of character priorities. The present assemblage is dealt with under this philosophy.

The water chemistry of Lake Gnotuk is also tabulated (Table 1) because it seems highly probable that dinoflagellate assemblages are particularly sensitive to this environmental parameter as a comparison between the assemblages of Harland and Sarjeant (1970), Norris and McAndrew (1970) and the present assemblage suggests.

## ACKNOWLEDGMENTS

The author would like to acknowledge the assistance of Dr. D. M. Churchill in providing the material for study, Dr. G. Playford for kindly reading and criticizing the manuscript, the Department of Geology, University of Alberta, for providing facilities for study and photography, and finally his wife for clerical assistance.

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## EXPLANATION OF PLATES 15 AND 16

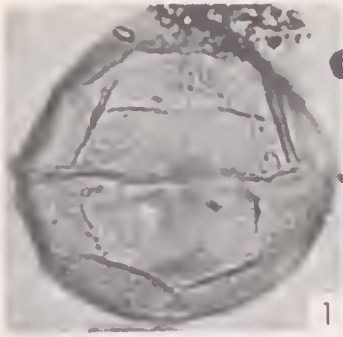
All photographs are at a magnification of  $\times 750$  except where otherwise stated.

## PLATE 15

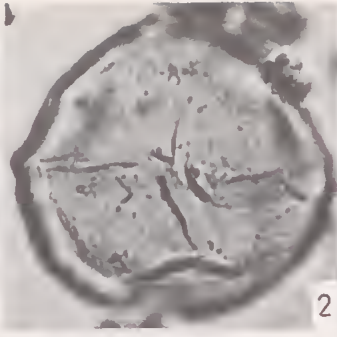
- FIG. 1—*Peridinium* sp. A, Dorsal view.
- FIG. 2—*Peridinium* sp. A, Ventral view.
- FIG. 3—? *Peridinium* sp. B, Dorsal view.
- FIG. 4—? *Peridinium* sp. B, Ventral view.
- FIG. 5—*Gonyaulax* sp. A, Dorsal view.
- FIG. 6—*Gonyaulax* sp. A, Ventral view.
- FIG. 7—*Gonyaulax* sp. A, Dorsal view.
- FIG. 8—*Gonyaulax* sp. A, Ventral view slightly oblique.
- FIG. 9—*Gonyaulax* sp. A, Median view slightly oblique.
- FIG. 10—*Diplopeltopsis* sp. A, Ventral view showing the archeopyle.
- FIG. 11—*Diplopeltopsis* sp. A, Dorsal view.
- FIG. 12—? *Aquadulcum* sp. A, Dorsal view.

## PLATE 16

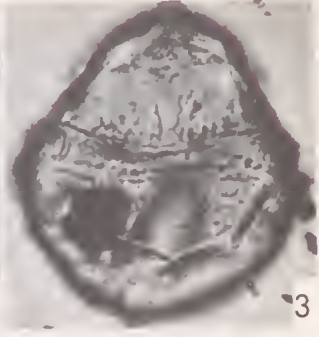
- FIG. 1—? *Aquadulcum* sp. A, Ventral view showing the archeopyle.
- FIG. 2—? *Aquadulcum* sp. B, Ventral view.
- FIG. 3—? *Aquadulcum* sp. B, Dorsal view showing the archeopyle.
- FIG. 4—? *Aquadulcum* sp. B, Median view.
- FIG. 5—? *Aquadulcum* sp. B, Ventral view.
- FIG. 6—? *Aquadulcum* sp. B, Median view.
- FIG. 7—? *Aquadulcum* sp. B, Dorsal view.
- FIG. 8—? *Aquadulcum* sp. A, Detail of archeopyle.  $\times 2,000$ .
- FIG. 9—? *Aquadulcum* sp. B, Detail of apex to show the structure.  $\times 2,000$ .
- FIG. 10—? *Aquadulcum* sp. B, Detail of archeopyle.  $\times 2,000$ .
- FIG. 11—? *Aquadulcum* sp. B, Detail of apex to show the delicate spine.  $\times 2,000$ .



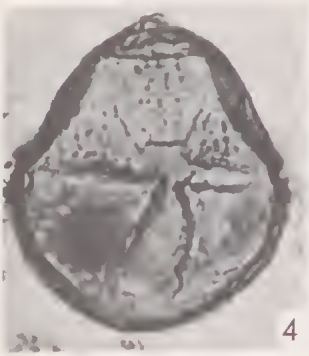
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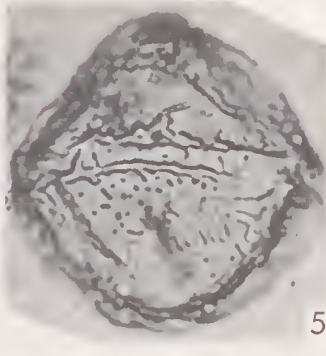
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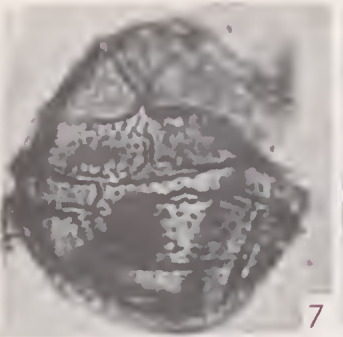
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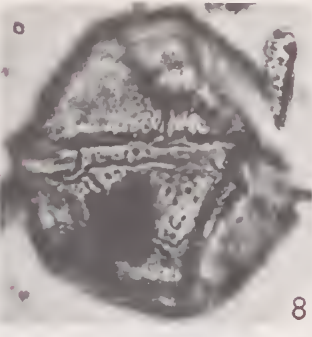
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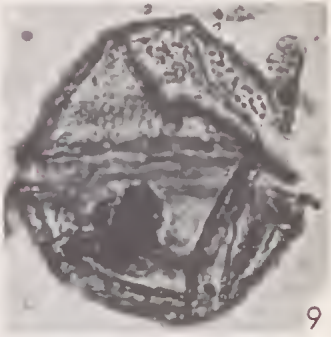
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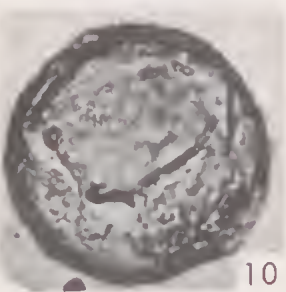
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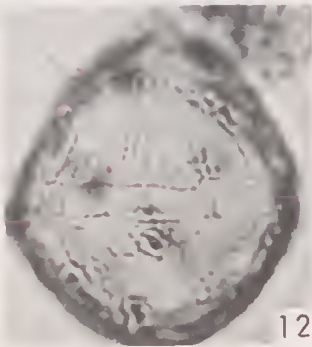
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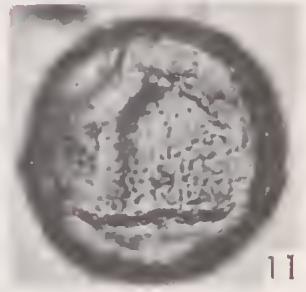
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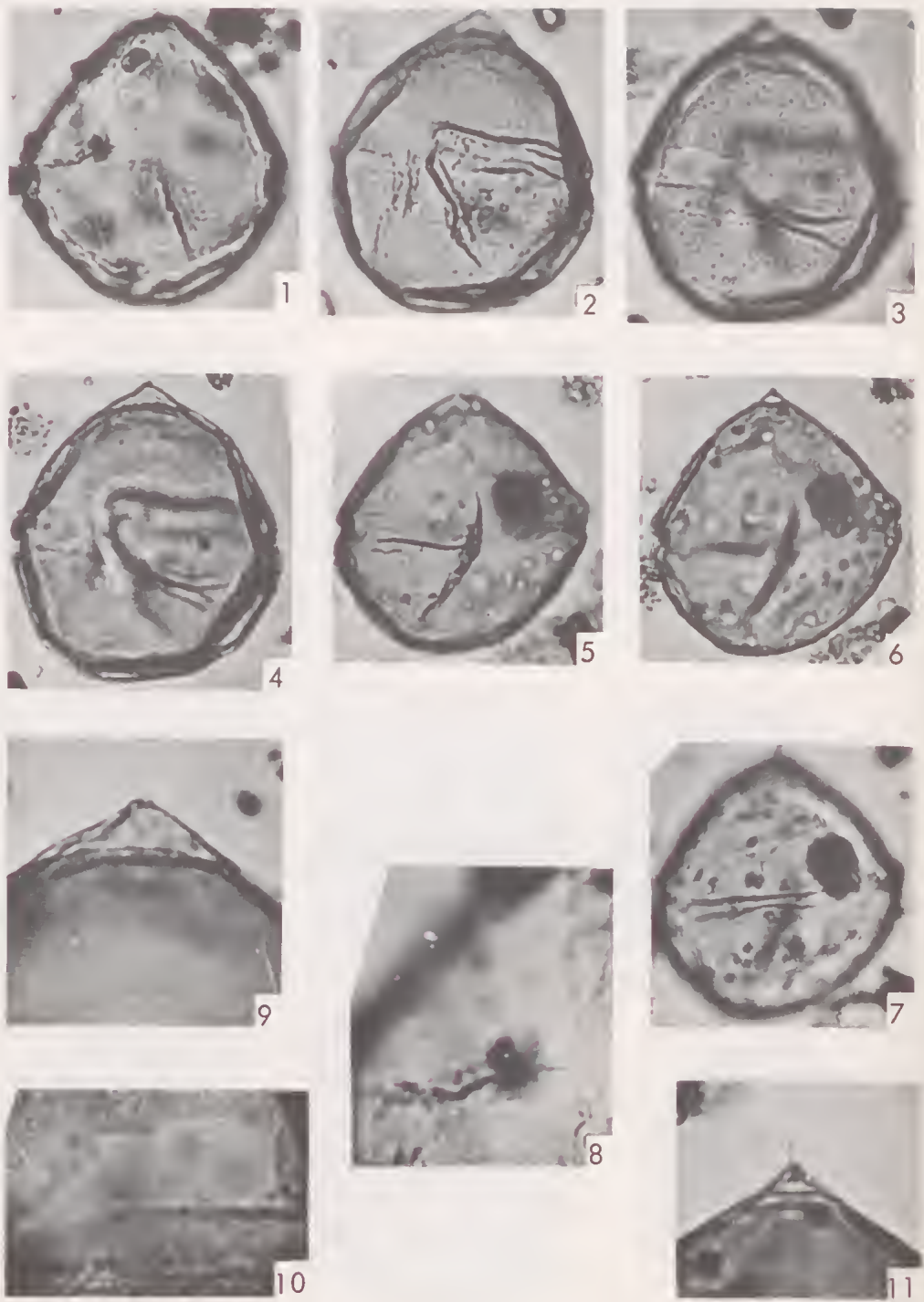
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## PRACTICAL APPLICATION OF THE ZÜRICH-MONTPPELLIER SYSTEM OF PHYTOSOCIOLOGY

By P. B. BRIDGEWATER\*

**ABSTRACT:** Practical application of the Zürich-Montpellier system of phytosociology is discussed. To illustrate its use and the methodology involved, reference is made to some vegetation samples from Westernport Bay, Victoria.

### INTRODUCTION

The Zürich-Montpellier (Z-M) system attempts to describe stands of vegetation, and then group similar stands, using floristic similarity as a criterion. Hence it is a polythetic divisive system (Williams, Lambert and Lance 1966).

It has been applied to most vegetation types, and has the advantage that surveys covering large or small areas can be easily undertaken. Stand groups (usually arranged in a hierarchical structure) are particularly suitable for vegetation mapping.

There has been surprisingly little published in the English language on the theory and practice of the Z-M system. Notable exceptions have been Becking (1957) and Poore (1955a, b, c, 1956). Both of these authors dealt rather more with theoretical aspects of the system than with an explanation of the system's methodology.

More important, both freely utilize the concept of fidelity. Although this concept played an important part in the system's development, few proponents of the system now utilize it. Moore (1962), in commenting on Poore's (loc. cit.) observations, noted that the use of 'Charakterarten' (characteristic species) has now declined, and been largely replaced by 'Trennarten' (differential species). 'Differential species' implies that the species concerned serve to differentiate a unit of vegetation from similar units, but does not imply that the species is necessarily confined to that unit. The Trennarten of associations, taken as the basic units of the Z-M hierarchy, are termed 'Kennarten'.

As further comment on this problem, Ellenberg (1960) wrote '... the importance of characteristic species, or species of high fidelity, is decreasing more and more, and they only become important

in the higher units of the system (alliance, order, class)'.

The system has been applied extensively in Europe, North and South America and Japan. That it can also be applied with great benefit in Australia the author has no doubt, and the prime reason for publishing this paper is to bring the methodology of the system within the reach of Australian ecologists who may wish to experiment with it.

### METHODOLOGY

Two distinct phases are involved: 1. analysis (= description) and 2. synthesis (= classification).

#### 1. ANALYSIS

Here the most important feature involves 'stand selection', i.e. deciding the location and size of vegetation stands. ('Stand' is equivalent to the French 'Relevé', and German 'Aufnahme'.)

Stand selection depends on two major criteria:

- Vegetational homogeneity;
- Vegetation 'minimal area'.

Dahl and Hadeč (1949) give the following definition of **homogeneity**:

A *plant species* is said to be homogeneously distributed within a certain area, if the probability of catching an individual of the species, within a test area, is the same in all parts of the area. A plant community is said to be homogeneous if the individuals of the component species, used for community characterisation, are homogeneously distributed.

Poore (1955b) noted:

... it is quite clear that homogeneity is a matter of scale ... In fact, the more one examines vegetation, the more one is forced to the conclusion that absolute uniformity is an illusion.

Bearing this in mind, it is nevertheless possible to distinguish between vegetation that approxi-

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mates to a standard of homogeneity, and one which is non-homogeneous (viz. the 'ecotone' between two well-defined vegetation types). Should such gradal situations be described, they will become obvious in the synthetic phase, and are best offset in any final tables of the vegetation.

Vegetation which obviously forms a mosaic is usually best treated as two vegetation types. Subsequent treatment in the synthesis phase may confirm this treatment, or show the mosaic effect to be produced by dominants only, and not borne out by total species composition.

Continental European phytosociologists have long relied on 'die pflanzensoziologische Blick', or assessment of homogeneity by eye. Many 'Anglo-American' ecologists have criticized this, perhaps unaware that it is not a haphazard process, but one in which the physiognomic structure of vegetation is assessed according to a very definite 'rule' of homogeneity.

If, at any stage, there are doubts regarding the homogeneity of any vegetation stand being described, then a note to this effect should be added.

'Minimal area' is based on the premise that the true characteristics of a plant community need a minimum area for expression, and any smaller areas examined would not indicate the full community characteristics. However, at the start of any investigation, no communities have been defined.

To overcome this circular argument, it is generally accepted that plant formations (sensu Dansereau 1957) are composed of communities with similar minimal areas. When working in a new formation, or unusual vegetation, an estimate of minimal area can be made using the following procedure:

- Within an area  $0.5 \times 1$  m count the number of species.
- Double the area of the quadrat (i.e.  $1 \times 1$  m), keeping the original area examined within the new area. Note any new species.
- Continue this procedure, plotting the number of species noted against quadrat size.
- The resultant graph should be a curve, with an initially sharp rise, but which levels out, or has a much diminished rate of increase.
- The point of intersection between a perpendicular, dropped from the curve at the point of levelling out, and the horizontal axis is taken as the minimal area.

Assuming the vegetation to be homogeneous, and an area  $>$  the minimal area has been chosen, the following procedure should be adopted:

(1) Each description must have a unique code. This can vary with the purpose and needs of the recorder, i.e. it can be simple (1, A, etc.) or more

detailed (PB/1/H), i.e. Author, number, vegetation type.

(2) For each description note:

- Locality, as precisely as possible. (N.B.: in areas that are unmapped or have only old maps, a tracing sheet placed over an aerial photograph is a good method to show stand location, especially if there is a cluster of stands in an otherwise undistinguished region.)
- Date—always in full, preferably as shown—12/X/'70 (i.e. day, month, year).
- \*e. Grid Reference
- \*d. Altitude
- e. Slope
- †f. Exposition
- †g. Aspect
- h. Tree layer height, % cover
- i. Shrub layer height, % cover
- j. Herb (field) layer height, % cover
- k. Bryophyte (ground) layer height, % cover
- l. Total Vegetation cover (%)
- m. Where appropriate, note % cover of bare ground, rock or open water.
- n. Area of the stand being analysed

\* These details may be added later from maps or other sources.

† 'Aspect' here refers to the most obvious feature of the vegetation (i.e. a species in full bloom); 'Exposition' to the compass point.

(3) In addition, a small sketch of the stand location is often useful.

(4) Soil profile; geological substratum. These are invaluable supplements to vegetation description. A sketch should be made of soil profile, noting any special features, particularly the development of the organic fraction. If possible, differentiate litter (L), fermentation (F) and humus (H) layers, leaching effects, water level, etc. In detailed studies, soil samples may be required for pH and mineral analysis. Distinguish solid and drift geological substrata, and note any outcrops.

(5) Note any unusual feature, i.e. roadside, regularly disturbed, subject to sea-spray, etc.

(6) Add any biotic data you consider important, i.e. intensive grazing (specify animal(s) if possible), excessive ant activity, etc.

(7) Make a complete list of all species present—include bryophytes, lichens and, if present, macroscopic algae. Epiphytes should be noted as such, but in certain vegetation types (e.g. Rain forests) it is possible that the epiphytic communities should be described separately (see Barkman 1959).



(8) Each species should then be assigned a value on a cover abundance scale, and, if possible, a sociability (mode of growth) scale. The use of these scales serves a two-fold purpose:

(i) they create a mental picture (for readers) of the vegetation described, and  
 (ii) they help to distinguish vegetation types, which, although floristically similar, may have different species acting as dominants. This is especially important in species-poor vegetation. Although there are several scales of cover-abundance in the literature, unless detailed work is being carried out the scale least subject to 'operator error' is that of Braun-Blanquet (1928) (see Appendix). Other scales, suitable for more detailed work, are those of Domin (1933), Doing-Kraft (1954), Barkman, Doing and Segal (1964). Note here also that 'cover' is defined as the 'amount of ground space that would be covered by an irregular polygon tracing the outline of the plant'. For a justification, see Daubenmire (1968).

(9) In the early days of the systems' development 'vitality' and phenology (i.e. seedling, flowering, fruiting, etc.) were also noted for each species, on a 1-5 scale. However, the use of these has been largely discontinued, with the exception that tree or shrub seedlings are usually noted separately, e.g. *Eucalyptus regnans* 5.1, *E. regnans* (seedlings) 1.1.

In extended surveys, it is often useful to have cards pre-printed with headings noted above, and a list of the more common species involved.

## 2. SYNTHETIC PHASE

As an example of this phase, 22 vegetation stands (each 5 sq. m in area) (taken from salt marsh vegetation, Westernport Bay, Victoria) are used for a step-by-step illustration of stages involved. The values quoted are from the cover-abundance and sociability scales of Braun-Blanquet (1928), with cover-abundance being quoted first. Although the tables are shown typed, normally they would be hand written.

(1) All stands are entered in a stands/species table (Table 1). This is the 'raw table'.

(2) This is then examined, and 'potential differential species' (PDS) noted. This has been done in Table (2), although normally one would use the raw table. The initial choice is made from species having an apparently clumped distribution, with usually < 60% presence in the stand group. Species such as *Distichlis distichophylla*, which may be a PDS, are ignored at this stage, but subsequently reordering may highlight this and other species, not obvious in this initial selection.

In the example there are 4 obvious groups of PDS:

- the coincidence of *Atriplex cinereum* and *Selliera radicans*.
- the coincidence of *Triglochin striata* and *Hemichroa pentandra*.
- the coincidence of *Carpobrotus rossii*, *Poa poiformis*, *Triglochin striata* and *Frankenia pauciflora*.
- The coincidence of *C. rossii*, *P. poiformis*, *Gahnia filum*, *Suaeda australis* and *F. pauciflora*.

At this stage, there is obvious overlap between (c) and (d)—subsequent testing will reveal if the distinction should be maintained.

(3) Using those species a new table (3) (the 'partial table') is drawn up, with a new order of stands, consolidating separated stands of the four groups discussed above. For easy and efficient transfer of information between the tables, the following procedure is recommended.

Two strips of squared paper are used, one with the numbers 1-22 entered sequentially. This is placed over the recorded stand numbers on the partial table. The second strip is placed over the raw table, and the position of the stand, as determined by its order in the partial table, is entered. Thus over stand 1 in the raw table 1 is entered, stand 2-2, stand 3-19, stand 4-20, etc. The two strips are illustrated under Table 3 (Fig. 1).

(4) From this partial table, it becomes obvious that there are, in fact, 3 species groups, each determined by a pair of species, and each capable of further differentiation. The three pairs are:

- Atriplex cinereum*—*Selliera radicans*
- Triglochin striata*—*Hemichroa pentandra*
- Poa poiformis*—*Frankenia pauciflora*

It is also obvious that to clarify the subdivisions of (iii) a rearrangement of stands would help, i.e. as 13, 15, 3, 4, 14, 5, 6.

(5) Next a new partial table, with all species (excepting those of only one occurrence) is drawn up. This step may highlight any PDS previously ignored, and consolidate differentiated groups noted in 4. Again, transfer strips are used for ease in handling the data. This is Table (4) (partial table II).

(6) From the information gathered from partial table II, a third partial table (Table 5) is drawn up, revising the order of species. Stand 15 appears rather anomalous—this is set to one side for further consideration, but otherwise the stand order is unchanged. It can be useful, at this stage, to space out the defined groups.

It should be stressed that transfers of species values are made each time from the raw table,



and never from partial table to partial table.

(7) This last Table (5) represents the state of the vegetation as far as our knowledge extends at the time of investigation. Gathering of further stands, however, may increase the information, indicating a need for fusion, or perhaps subdivision, of the units described above.

## NOMENCLATURE

Associations are usually named from a species acting as a physiognomic dominant, and another species constantly present, but not necessarily a physiognomic dominant. Similar associations, differentiated from others by the same set of differential species, may be grouped as alliances, and similar alliances grouped as orders, etc.

The 'endings' for the various hierarchical ranks are cited below (lowest rank at bottom):

Class	-etea
Order	-etalia
Alliance	-ion
Association	-etum
Sub-Association	-etosum
Variant	no ending, or -osum

To illustrate the three associations from this example three 'final tables' have been prepared (6-8).

These three associations most probably belong to the class Thero-Salicornietea.

## ACKNOWLEDGMENTS

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## APPENDIX:

### A. COVER/ABUNDANCE SCALE

The one recommended is that of Braun-Blanquet (1928), i.e.:

- r = erratic, cover less than 5%.
- + = occasional cover, less than 5%.
- 1 = common, cover less than 5%.
- 2 = very common, cover less than 5% or cover 5-20%, any no. of individuals.
- 3 = cover 20-50%, any no. of individuals.
- 4 = cover 50-75%, any no. of individuals.
- 5 = cover 75-100%, any no. of individuals.

### B. SOCIABILITY

Braun-Blanquet (1928):

- 1 = growing singly; solitary plants.
- 2 = growing in groups; clumps or tufted plants.
- 3 = large groups or clumps; small scattered patches.
- 4 = patches, or broken mat.
- 5 = extensive mat, covering nearly all stand area.

Note: The + symbol is not usually associated with values on the sociability scale.

TABLE 1  
RAW TABLE

[illegible]

TABLE 2

RAW TABLE—INDICATING 'POTENTIAL DIFFERENTIAL SPECIES'

[illegible]

TABLE 3  
PARTIAL TABLE I

	1	2	10	11	12	16	17	7	8	9	18	19	20	21	22	13	14	15	3	4	5	6
<u>Atriplex cinereum</u>	+	+	+	+	1.2	1.2	+															
<u>Selliera radicans</u>	1.2	2.1	+	+	+	+	1.1								1.1	2.2						
<u>Triglochin striata</u>			+					2.1	2.1	1.1	1.1	2.1	+	2.1	2.1		2.2	+			1.2	+
<u>Hemichroa pentandra</u>						1.2	+	2.1	3.2	2.1	4.4	2.1	5.5	3.3	3.3							
<u>Carpobrotus rossii</u>						4.4																
<u>Poa poiformis</u>																3.3		3.3	3.3	4.4		
<u>Frankenia pauciflora</u>																1.2	1.2	1.2	1.2	2.2	2.2	1.2
<u>Gahnia filum</u>			2.2	2.2	2.2											3.3	2.1	3.3	3.3	1.1		2.3
<u>Suaeda australis</u>						1.1	1.1	1.1								3.2			3.2	2.2		
																			1.1	+		

Fig. [1]

Strip sequence:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	[ PARTIAL TABLE ]																					
revised stand order:	1	2	10	11	12	16	17	7	8	9	18	19	20	21	22	13	14	15	3	4	5	6
Strip sequence:	1	2	19	20	21	22	8	9	10	3	4	5	16	17	18	6	7	11	12	13	14	15
	[ RAW TABLE ]																					
original stand order:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22

TABLE 4  
PARTIAL TABLE II

	1	2	10	11	12	16	17	7	8	9	18	19	20	21	22	13	15	3	4	14	5	6	
<u>Atriplex cinereum</u>	+	+	+	+	1.2	1.2	+																
<u>Selliera radicans</u>	1.2	2.1	+	+	+	+	1.1						+	1.1	2.2								
<u>Triglochin striata</u>			+			+		2.1	2.1	1.1	1.1	2.1	+	2.1	2.1		+			2.2	1.2	+	
<u>Hemichroa pentandra</u>						1.2	+	2.1	3.2	2.1	4.4	2.1	5.5	3.3	3.3								
<u>Poa poliformis</u>																	1.2	1.2	1.2	2.2	1.2	2.2	1.2
<u>Frankenia pauciflora</u>																	3.3	3.3	3.3	1.1	2.1		2.3
<u>Carpobrotus rossii</u>						4.4											3.3	3.3	3.3	4.4			
<u>Gahnia filum</u>			2.2	2.2	2.2												3.2		3.2	2.2			
<u>Suaeda australis</u>						1.1	1.1	1.1											1.1	+			
<u>Salicornia quinqueflora</u>	3.3	4.4	3.3	4.4	3.3	3.1	2.1	1.1	2.1	5.5	3.1	1.1	2.1	2.1	3.1		3.3	2.1	3.3	4.4	5.5	2.2	
<u>Arthrocnemum arbusculum</u>	4.4	4.4	4.4	3.1	5.5	4.4	5.5	2.1	2.1			+		1.1	+	3.1			3.1			+	
<u>Distichlis distichophylla</u>	3.3	2.2	2.2	3.3	3.3	1.2	1.2				+	1.2	+	2.2	+	2.2		2.2					
<u>Samolus repens</u>	1.2	2.3	2.3	2.3	1.3	3.3	3.2	5.5	3.3	2.2		5.5	1.1	3.3	2.2	+		+	1.1	1.1	+		
<u>Parapholia incurva</u>																1.2		2.2				2.2	
<u>Limonium australis</u>								1.1				1.1		2.1									
<u>Rhizoclonium spp.</u>						3.3	4.4																





TABLE 5  
PARTIAL TABLE III

	1	2	10	11	12	16	17	7	8	9	18	19	20	21	22	13	3	4	14	5	6	15
<u>Atriplex cinereum</u>	+	+	+	+	1.2	1.2	+															
<u>Selliera radicans</u>	1.2	2.1	+	+	+	+	1.1						+	1.1	2.2							
<u>Arthrocnemum arbusculum</u>	4.4	4.4	4.4	3.1	5.5	4.4	5.5	2.1	2.1			+		1.1	+	3.1	3.1	3.1			+	
<u>Distichlis distichophylla</u>	3.3	2.2	2.2	3.3	3.3	1.2	1.2				+	1.2	+	2.2	+	2.2	2.2					
<u>Triglochin striata</u>			+			+		2.1	2.1	1.1	1.1	2.1	+	2.1	2.1				2.2	1.2	+	+
<u>Hemichroa pentandra</u>						1.2	+	2.1	3.2	2.1	4.4	2.1	5.5	3.3	3.3							
<u>Poa poliformis</u>																1.2	1.2	2.2	1.2	2.2	1.2	1.2
<u>Frankenia pauciflora</u>																3.3	3.3	1.1	2.1		2.3	3.3
<u>Carpobrotus rossii</u>						4.4										3.3	3.3	4.4				3.3
<u>Gahnia filum</u>			2.2	2.2	2.2											3.2	3.2	2.2				
<u>Suaeda australis</u>					1.1	1.1	1.1										1.1	+				
<u>Rhizoclonium spp.</u>						3.3	4.4															
<u>Samolus repens</u>	1.2	2.3	2.3	2.3	1.3	3.3	3.2	5.5	3.3	2.2		5.5	1.1	3.3	2.2	+	+	1.1	1.1	+		

TABLE 6  
ARTHROCNEMO—ATRIPLICETUM CINEREI

	1	2	10	11	12	16	17	
DIFFERENTIAL SPP. OF THE VARIANTS:								
<u>Gahnia filum</u>			2.2	2.2	2.2			
<u>Hemichroa pentandra</u>						1.2	+	
<u>Suaeda australis</u>					1.1	1.1	1.1	
<u>Rhizoclonium spp.</u>						3.3	4.4	
DIFFERENTIAL SPP. OF THE ASSOCIATION:								
<u>Arthrocnemum arbusculum</u>		4.4	4.4	4.4	3.1	5.5	4.4	5.5
<u>Distichlis distichophylla</u>		3.3	2.2	2.2	3.3	3.3	1.2	1.2
<u>Atriplex cinereum</u>		+	+	+	+	1.2	1.2	+
<u>Selliera radicans</u>		1.2	2.1	+	+	+	+	1.1
SPECIES OF THE ALLIANCE:								
<u>Salicornia quinqueflora</u>		3.3	4.4	3.3	4.4	3.3	3.1	2.1
<u>Samolus repens</u>		1.2	2.3	2.3	2.3	1.3	3.3	3.2
ADDITIONAL SPECIES:								
<u>Triglochin striata</u>					+		+	

TABLE 7  
TRIGLOCHIO—HEMICHROETUM PENTANDRAE

	7	8	9	18	19	20	21	22
DIFFERENTIAL SPP. OF THE VARIANTS:								
<u>Arthrocnemum arbusculum</u>	2.1	2.1				1.1	+	
<u>Selliera radicans</u>						1.1	2.2	
<u>Distichlis distichophylla</u>						1.2	2.2	+
DIFFERENTIAL SPP. OF THE ASSOCIATION:								
<u>Triglochin striata</u>	2.1	2.1	1.1	1.1	2.1	+	2.1	2.1
<u>Hemichroa pentandra</u>	2.1	3.2	2.1	4.4	2.1	5.5	3.3	3.3
SPECIES OF THE ALLIANCE:								
<u>Salicornia quinqueflora</u>	1.1	2.1	5.5	3.1	1.1	2.1	2.1	3.1
<u>Samolus repens</u>	5.5	3.3	2.2		5.5	1.1	3.3	2.2
ADDITIONAL SPECIES:								
<u>Limonium australis</u>	1.1				1.1		2.1	

TABLE 8  
FRANKENIO—POETUM POIFORMIS

	13	3	4	14	5	6
DIFFERENTIAL SPP. OF THE VARIANTS:						
<u>Arthrocnemum arbusculum</u>	3.1	3.1	3.1			
<u>Carpobrotus rossii</u>	3.3	3.3	4.4			
<u>Gahnia filum</u>	3.2	3.2	2.2			
<u>Distichlis distichophylla</u>	2.2	2.2				
<u>Suaeda australis</u>		1.1	+			
<u>Triglochin striata</u>				2.2	1.2	+
DIFFERENTIAL SPP. OF THE ASSOCIATION:						
<u>Poa poiformis</u>	1.2	1.2	2.2	1.2	2.2	1.2
<u>Frankenia pauciflora</u>	3.3	3.3	1.1	2.1		2.3
SPECIES OF THE ALLIANCE:						
<u>Salicornia quinqueflora</u>		2.1	3.3	4.4	5.5	2.2
<u>Samolus repens</u>	+	+	1.1	1.1	+	
ADDITIONAL SPECIES:						
<u>Parapholis incurva</u>						2.2

# A RE-EXAMINATION OF *PSILICHTHYS SELWYNI* HALL, FROM THE LOWER CRETACEOUS OF VICTORIA

By M. WALDMAN\*

**ABSTRACT:** *Psilichthys selwyni* Hall 1900, which has been assigned to various higher taxa since its original description, is re-examined. Several features previously unobserved are noted, such as the presence of cycloid scales and pelvic fins, and the fish is referred to the Sub-order Palaeoniscoidei; possibly belonging to the family Coccolepididae.

## INTRODUCTION

Since Hall's original study in 1900, no further work on this fish has appeared in print, apart from classifications, and from the latter it is apparent that most authors have referred only to the original description and have not seen the material. During the course of a study of Victorian Mesozoic fish, *Psilichthys* was examined and it became evident that a redescription was necessary. Hall (1900) did not observe a number of important features, thereby misinterpreting the specimen.

## SYSTEMATIC DESCRIPTION

Order PALAEONISCIFORMES

Sub-order PALAEONISCOIDEI

Family ? COCCOLEPIDIDAE Berg 1940

Genus *Psilichthys* Hall 1900

**EMENDED DIAGNOSIS:** A large fish; fusiform to slightly deepened body. Dorsal fin with axonosts and baseosts, anal with single row of axonosts. At least fourteen expanded haemal spines support tail. Twenty-seven dorsal fin axonosts; fourteen anal fin axonosts. Forty unbranched pelvic fin-rays; anal and caudal fin lepidotrichia unbranched. Fins long-based, pelvic without fulcra; strong fulcra on caudal fin dorsal lobe. Caudal, anal and pelvic fins close together. Scales cycloid, except on dorsal caudal lobe where they are lanceolate. Lanceolate scales probably enamelled.

*Psilichthys selwyni* Hall 1900

**DIAGNOSIS:** As for genus; sole specimen.

**HOLOTYPE:** P12987, National Museum of Victoria.

**HORIZON:** Lower Cretaceous; Korumburra Group (see Dettmann 1963 for age determination of Korumburra Group).

**LOCALITY:** Hall (1900) stated: 'Carrapook (Muntham), county of Dundas, Western Victoria. From a tank sunk by Mr. Stock at his house, . . .' This tank has been relocated on the site of the old 'fattening paddock', close to the intersection of Wennicott Creek with the Glenelg Highway, on the north side of the highway at the 211 mile post. The site is on Block 8 of the McNichols Estate, bounded to the east by Featherstonhaugh Road and to the south by the Glenelg Highway.

**MATERIAL:** This comprises the posterior portion of the fish and consists of three main blocks. These bear: 1. Posterior axial skeleton, caudal and anal fins; 2. Axial skeleton with part of the dorsal fin and pelvic fin supports; 3. An isolated pelvic fin.

These blocks are embedded in plaster surrounded by a heavy wooden frame. As the rock-matrix is crumbling and at least partly attached to the plaster, no attempt has been made to remove the specimen, bearing in mind its unique nature.

## DESCRIPTION

The axial skeleton consists of a series of neural and haemal arches fused to their respective spines (Pl. 17, 18, 19). There is no trace of any calcification in the sheath of the persistent notochord. The neural arches and spines lying beneath the anterior region of the dorsal fin are comparatively slender and curve toward the posterior in a shallow arc. They become progressively more robust posteriorly beneath the dorsal fin supports, with an obtuse angle on the anterior margin where arch and spine meet. Beyond the posterior margin of the dorsal fin supports, some of the neural spines and arches have rotated slightly on their long axes during preservation and the aperture of the arch is visible. These spines lie at a shallower angle to the notochord than do the more anterior elements, the last one or two having spatulate or 'oar-blade'

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distal regions. Beyond this point there is a sudden change in the character of the neurals, accentuated by the mode of preservation. The spatulate distal spine of the last neural noted appears to almost articulate with what seems to be the 'first neural' of the caudal region. It is slender and does not resemble the other caudal neurals. In fact this represents a dorsal displacement of the caudal neural spines and the last of the body neurals has been deflected dorso-laterally to reveal the neural arch. Posteriorly the neural arches (viewed laterally) are broad proximally and taper distally into the posteriorly-curving neural spines. The obtuse angle of their anterior margins measures about 150° and points posteriorly, unlike those beneath the dorsal fin, in which the angle points anteriorly.

The haemal arches and spines begin at about the level of the middle of the dorsal fin. Hall (1900) stated that they were '... similar to the neural, but the anterior ones are forked at their inner ends'. The 'fork' is the haemal arch, visible due to displacement of the bones. Five haemals are visible on the most anterior block of the specimen and another six may be counted before the first haemal supporting the caudal fin is reached. At least fourteen haemal spines support this fin, many of the anterior ones being very much thickened and expanded, with long, wide arches. They decrease rapidly in size posteriorly.

**UNPAIRED FINS:** The dorsal fin supports are clearly visible, there being two series, axonosts and baseosts. At least twenty-seven axonosts are present, becoming shorter posteriorly. They begin by being inclined antero-ventrally, are vertical by the level of the middle of the fin and then begin to be aligned postero-ventrally. The last seven are either vertical or tilted antero-ventrally. These were clearly figured by Hall (1900) and most are somewhat broadened proximally. Axonost fifteen (numbering from the anterior) is the broadest and is also forked proximally. The long, slender anterior axonosts show a narrow distal bifurcation, this dichotomy being broader in the middle of the series and reaching a maximum between axonosts sixteen to twenty. A fragment of a hollow but well-ossified bone shaft is preserved in the ninth element of the series. All other axonosts are represented by impressions.

The baseosts are poorly preserved, appear to reach a maximum size of about half the length of the axonosts and are inclined antero-ventrally. They are expanded or possibly bifurcate distally, but the proximal regions are obscured. There are at least forty-three jointed lepidotrichia, the proximal segment being longer than successive divisions. Although most of the distal portion of the dorsal fin has been destroyed, it is possible to state that it was long-based, being at least 100 mm in length.

The anal fin supports consist of a single row of at least fourteen axonosts, more originally having been present beyond the broken anterior margin of the

fin. They are slim, hollow tubes of bone, slightly expanded proximally, and more so distally. At a cursory glance there appears to be part of a second row of endoskeletal elements present posteriorly, but this represents a series of primary proximal joints of the lepidotrichia, some displacement of the fin elements having occurred. These proximal fin-ray joints are triangular in isosceles fashion, with the apex of each pointing antero-dorsally. Some of the posterior segments still possess bone and are, therefore, more obvious than the others. At least forty-eight lepidotrichia are preserved, but undoubtedly more were present at the anterior edge of the fin. They are jointed and become more slender posteriorly. At the posterior margin of the fin a few small complete lepidotrichia are visible, showing a distal dichotomy.

The endoskeletal supports of the caudal fin have already been mentioned (see 'axial skeleton') and only the ventral fin-rays are preserved to any degree. It is difficult to count the lepidotrichia with any accuracy, particularly as they begin the first several bifurcations very close to their origins. There appear to be twenty-six in the ventral lobe, the first segment of each being several times as long as succeeding ones. Nothing is known of the lepidotrichia of the dorsal lobe, but to judge from the number and spacing of the bifurcations in the medial region of the fin, the whole fin was deeply cleft.

**PAIRED FINS:** A single isolated fin is present on the most anterior block of the specimen (Pl. 17, fig. 2). This fin was not mentioned by Hall (1900), but is set in the plaster well ahead of the other two blocks. Its dorsal surface bears four slender, curved, rod-like impressions which are expanded distally, the rest of the surface having been weathered away. The dorsal and vertical faces of the block bear another six which are followed posteriorly by fragments of several more. On Block 2, anterior to the level of the first haemal there are nine similar impressions and on the vertical face of this block there are six more of these curved rods, together with the proximal joints of a number of lepidotrichia. It is evident, therefore, that this paired structure of curved rods represents the supporting structure of paired fins, the pelvic fins. Although the edges of the one well-preserved pelvic fin are broken away, mainly at the posterior margin, little of the fin is missing, its original shape being that of an equilateral triangle. Forty articulated lepidotrichia are preserved and there may have been a few more originally. They are uniramous, robust, consist of comparatively small segments and lack fulcra.

**SQUAMATION:** Hall described and illustrated five rows of lanceolate scale impressions on the upper caudal lobe, but only four such rows are present. Very thick fulcral scales overlie the dorsal margin of the dorsal caudal lobe. Hall mentioned '... a thin raised line of ferruginous material ...' which cuts across the dorsal part of the caudal neural spines. He interpreted this as indicating a possible division of the spines into two series of elements. This impermanent 'raised line' represents the lower margin of a series of impressions of a further row of scales, laterally over-

lying the neural spines. Despite Hall's statement of the presence of fulcral scales in front of the dorsal fin, I cannot find any evidence of such scales in that position. Due to the broken anterior margin of the anal fin, nothing is known of similar scales in that area.

According to Hall the fish did not bear any scales on the body, hence the generic name. This is incorrect, as scales are preserved in several areas of the body. A row of scales runs for a distance along the lower edge of the notochordal sheath and parts of at least two more scale rows are visible overlying part of the dorsal fin supports. Another two scales may be seen covering the proximal segments of some fin-rays of the lower caudal lobe. These scales are cycloid, exhibit strongly marked circuli, but appear otherwise non-ornamented. Poorly preserved scale imprints may be determined in other regions of the trunk, but only with the use of low-angle illumination.

#### REMARKS

A detailed examination of *Psilichthys* has shown that the preservation of its scales has depended upon the elevation and depression of the preserved surfaces. Almost all the body scales known are preserved in hollows or shallow depressions in the matrix, the raised regions being bereft of scales. The three fragmentary rows mentioned all occur in longitudinal hollows. The specimen shows very little bone, this probably having been stripped away by weathering and most elements are represented by impressions in the matrix. It is surely evident that one would not expect preservation of scales under such conditions, apart from odd exceptions, particularly if the scales were thin. The nakedness of the specimen is undoubtedly a vagary of preservation and no taxonomic significance should be attached to this or to the etymology of the name *psilichthys*.

The taxonomic assignment of *Psilichthys* has been a problem ever since Hall (1900) described it as possibly being related to *Chondrosteus*. Berg (1940) placed it within the Birgeriidae, while Romer (1945) classified it as belonging to the Chondrosteidae and in 1966 as pertaining to the Birgeriidae. Gardiner (1967) in his classification of the Chondrostei included *Psilichthys* within the Errollichthyidae. It is evident that all these classifications were influenced by the misleadingly naked appearance of the body of the fish.

The presence of cycloid scales, combined with the Lower Cretaceous age lead one to think in terms of the Coccolepididae, but if Berg's (1940) definition of the family is upheld, then *Psilichthys* is precluded by the presence of both axonosts and baseosts supporting the dorsal fin. Even though the Coccolepididae (Berg 1940) are supposed to have only one set of dorsal fin supports, Stensiö (1921) reported finding indications of baseosts in

the dorsal fin of a specimen of *Coccolepis bucklandi* (the type species). The positions of the known fins of *Psilichthys* are closely similar to those of the coccolepid *Sunolepis yumenensis* (Liu 1957), although this arrangement is common to many palaeoniscoids (Gardiner 1967). Further resemblances to *Sunolepis* are indicated by the change in shape and size of the caudal neurals at the same point and by the eyeloid, apparently non-tuberculate scales. It is possible, however, that the scale similarity may be due to convergence with *Psilichthys* representing the survival of a separate palaeoniscoid family into the Lower Cretaceous.

There is little to preclude *Psilichthys selwyni* from the Palaeoniscoidae and although its exact affinities must remain doubtful until more material is discovered, it appears to be closely related to known members of the Coccolepididae.

#### ACKNOWLEDGMENTS

I am indebted to Mr. T. A. Darragh, Curator of Fossils, National Museum of Victoria, for drawing my attention to this specimen, for allowing me to study it, and for helping to find the type locality. I wish to thank Professor J. W. Warren, Monash University, Department of Zoology, for helpful criticism of the manuscript and provision of facilities for study of the specimen. Mr. J. F. Gorman of Casterton, Mrs. E. E. Day of Coleraine and the *Casterton News* have all been of great help in the matter of relocating the provenance of *Psilichthys*. The work was undertaken during tenure of a Monash University Graduate Scholarship.

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## EXPLANATION OF PLATES 17-19

## PLATE 17

FIG. 1—*Psilichthys selwyni* Hall. Nat. Mus. Vict. P12987. Posterior portion of body without the pelvic fin;  $\times \frac{1}{2}$ .

FIG. 2—*Psilichthys selwyni* Hall. Nat. Mus. Vict. P12987. Pelvic fin;  $\times 1$ .

## PLATE 18

*Psilichthys selwyni* Hall. Nat. Mus. Vict. P12987. Central trunk region with anal and dorsal fin supports;  $\times 1$ .

## PLATE 19

*Psilichthys selwyni* Hall. Nat. Mus. Vict. P12987. Caudal fin;  $\times 1$ .



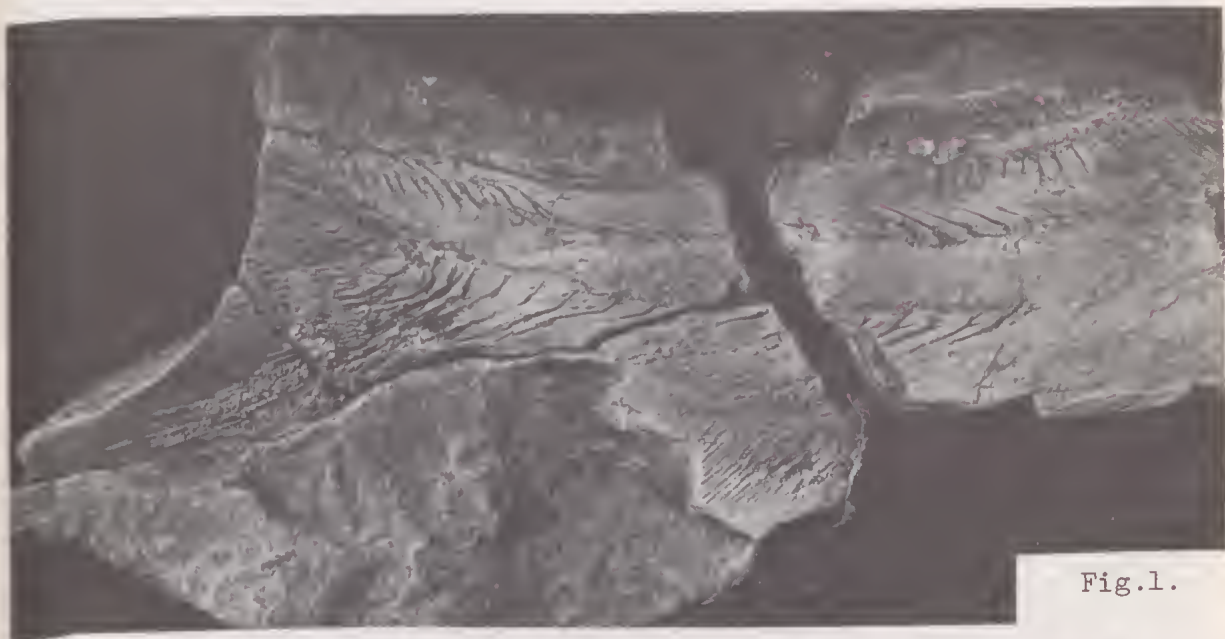


Fig.1.



Fig.2.











## SHORT COMMUNICATIONS

### THE BEGINNINGS OF SCIENCE IN VICTORIA

The beginnings of science in Victoria are impressive by reason of the early start in a struggling young colony, of the virility and scope of the activities, and of the high scientific standards of many of the participants. There were many strong personalities who were often in competition and sometimes in conflict. There are of course adequate reasons for all these characteristics. To understand the beginnings of science in Victoria requires some appreciation of the nature of the environment.

The area that became Victoria was at first simply a very distant pastoral district of the colony of New South Wales. From Sydney to Port Phillip was as far as from northernmost Scotland to the southern coast of England. Port Phillip was therefore very remote from Sydney, and it is not surprising that the initiative for its development came from the colony of Van Diemen's Land (Tasmania). Melbourne was not thought of until 1835 and then only in terms of a village. The pastoralists were scattered and their communications poor. They were struggling to establish themselves. Only in an economically stable township could scientific societies be effectively established. The organization of such societies is an expression of confidence in the continuity and success of the community. Two closely spaced events provided the required conditions. In 1850 the Port Phillip District was granted its independence and became a separate colony, and in 1851 gold was discovered.

Even with the lure of gold, it took considerable courage for people to leave their Home Country (probably for ever) and take the perilous six-month journey by sailing ship to the new colony. Many ships were lost and there were nearly always deaths en route even in the ships that suffered no calamity. There were many dangers in the new land, and there was always the fear of the unknown. Nor was there any assurance of economic security. Thus there was a selection factor that determined the strength of character, the drive, and the determination of the early settlers, including the scientists. It is not surprising that these strong personalities came into competition and at times into conflict. However, these same qualities account for the virility and remarkable scope of their activities.

Following the discovery of gold, Governor La Trobe requested geological assistance, and in May 1852 the geologist A. R. C. Selwyn was appointed for this purpose. This is how the Geological Survey of Victoria began. Its activities soon meant that more geologists were brought to the colony. R. Brough Smyth, who later became Secretary of Mines, and who also became the Honorary Secretary of the Philosophical Society of Victoria, migrated to the colony in 1852 when he was 22 years old. In 1853 the Gov-

ernment of Victoria decided to found an astronomical observatory. This began under the very competent direction of L. R. J. Ellery in a wooden building at Williamstown with very simple instruments. In 1858 the 'magnetic observatory' was established in the Flagstaff Gardens under another very competent person—G. Neumayr. The high standard of these and other early scientists is noteworthy. Neumayr was a foundation member of the Royal Society of Victoria. Both the Williamstown and Flagstaff Gardens sites proved to be unsuitable, so in 1863 these activities were concentrated at the Botanic Gardens. Thus the discovery of gold made a geological survey necessary, the mushroom growth of shipping made a meteorological observatory necessary, and other activities of the growing colony led to the arrival in Victoria of scientists who gradually constituted a scientific community from which scientific societies could emerge.

To understand the strange vegetation of the new colony was an obvious requirement, and so the pharmacist who became a noted botanist and explorer, Baron Sir Ferdinand von Mueller (as he ultimately became) established the National Herbarium which still functions strongly at the Royal Botanic Gardens. It is characteristic of the courage and energy of the early workers, that von Mueller immediately set out to traverse the colony and discover what its plants actually were. In 1853 he travelled to the Beechworth area and through the Buffalo Range (then practically unknown), on to the headwaters of the Goulburn River and through the La Trobe River in Gippsland, reaching Wilsons Promontory, and so ultimately back to Melbourne. This was a journey of exploration of 1500 miles, and quite a remarkable achievement. Later the same year he set off on a 1,000-mile journey through the Grampians to Albury and again east to Gippsland on the Tambo River and the Snowy River. Thus the needs and opportunities of the new colony brought together a quite remarkable group of scientific men. Economic advance meanwhile inspired confidence in the future of Victoria. Gold was a ready source of wealth, and other minerals were discovered. The pastoralists were no longer short of markets for their meat and wool. Agriculture began to develop, and there were the beginnings of secondary industries. Another expression of confidence was the construction of an elaborate Exhibition Building in William Street on the site that later accommodated the Royal Mint. The Exhibition was opened by the Governor Sir Charles Hotham, on 17th October, 1854. In this same year the colony's first railway line from Port Melbourne to the city of Melbourne was being expeditiously built, and the Town Hall was completed. In 1854 also two scientific societies were

begun, but somewhat in competition with one another. As further evidence that the young colony was scientifically on the move, we may note that in 1854 the National Museum was commenced in the Assay Office, largely through the efforts of an English army officer, Captain Andrew Clarke, R.E., who was the Surveyor-General of the colony. Some of the new museum's specimens were displayed in the Exhibition of that year. The first official appointment to the Museum staff was that of William Blandowski as zoologist. At first he had an active part in the scientific life of the community, and became a council member of the Philosophical Society. On June 27th, 1854, Blandowski set off on a scientific expedition to collect materials for the new natural history museum. In this same significant year of 1854 the new University of Melbourne was being formed, and Professor (later Sir) Frederick McCoy was appointed to the Chair of Natural History. McCoy was to become the first Director of the Museum. He is another example of the high calibre of early scientists in the colony.

Following the discovery of gold in 1851, the population of Melbourne had grown from 20,000 to 80,000 by 1854. It was only 17 years since the first land sales were held. In this city, then, two similar scientific societies were set up—the Victorian Institute for the Advancement of Science and the Philosophical Society of Victoria. W. S. Gibbons, an analytical chemist of 5 Collins Street East, and a lecturer at the Mechanics Institution, planned the former organization, which met in the Institution at which he lectured. With His Worship the Mayor of Melbourne in the chair, the Institute was inaugurated on 15th June, 1854. The aims were communication between people of scientific interest, exchange of information, a centre for the collection of observations and specimens, the development of the resources of the colony, and (characteristic of the times) 'the cultivation of a fine taste among the people of Victoria'. The laws of the Institute were based on those of the British Association for the Advancement of Science. The Governor was Patron, the Acting Chief Justice was President, Captain Clarke, Surveyor-General was Vice-President, John Maud, M.D., was Treasurer and W. S. Gibbons Honorary Secretary. The Council of nine included A. R. C. Selwyn and F. Mueller, already mentioned.

In September 1853 Captain Clarke had requested the Government to set aside a sum of money for the establishment of a museum. This the Colonial Secretary agreed to do 'if the honourable member and others who were interested in the subject, would form themselves into a committee, or initiate some society or institution which would co-operate with the Government. Captain Clarke called a meeting on 17th June 1854, and a committee was appointed to establish the Philosophical Society of Victoria. In time its simple aim was stated as 'embracing the whole field of science, with a special reference to the cultivation of those departments that are calculated to develop the natural resources of the country'. While the Victorian Institute for the Advancement of Science was modelled on the British Association, the Philosophical

Society was modelled on the Royal Society, the prospectus stating that 'after the grant of the Charter, this Society shall assume the title The Royal Society of Victoria.' The Patron was His Excellency the Lieutenant-Governor, the President was Captain Clarke, and the Vice-President was Dr G. Howitt. There were eight councillors (including Selwyn and Mueller), in addition to Dr D. E. Wilkie as Treasurer and Mr. S. Wekey as Honorary Secretary. It is interesting to note that Clarke, Selwyn and Mueller were common to the governing body of both societies. Gibbons appears to have been upset by the formation of the Philosophical Society, regarding it as a competitor started up because of the success of his Institute. However, it was soon clear that the young colony could not maintain two such societies, and the following year they were combined. Taking a word from the titles of each of the two original societies, the new one was called the Philosophical Institute of Victoria. The first meeting was held at the Museum. The new Institute was very active, studying the natural resources of the colony, the animals and plants that could be introduced with benefit, the establishment of an Astronomical Society, and the organization of a geographical expedition which ultimately resulted in the Burke and Wills Expedition. So it was that in 1859 Queen Victoria granted the title of Royal Society of Victoria. Very appropriately, the announcement was made by the Governor of Victoria, His Excellency Sir Henry Barkly, who was at that time President of the Society. He took an active part, chairing meetings and participating in discussion. Since then each Governor of Victoria has been Patron of the Royal Society of Victoria.

Another scientific beginning that merits record is that of the Zoological Society of Victoria, which was founded in October 1857. Like some of the other early scientific societies, it went through name changes, being incorporated in the Acclimatization Society in 1861, then becoming the Zoological and Acclimatization Society in 1872, and finally the Royal Zoological and Acclimatization Society in 1910. 'The objects of the Society', states a publication in 1861, 'shall be the introduction, acclimatization, and domestication of all innoxious animals, birds, fishes, insects and vegetables, whether useful or ornamental; the perfection, propagation, and hybridization of races . . .' and so on. Work began in the Richmond Paddock opposite the Botanic gardens, but 'the piece of land selected was cold, barren, and swampy,' so Mueller agreed to receive the plant specimens into his Gardens. The animals were removed to the present Zoological Gardens site in 1862.

The period was before the development of the sciences of genetics and ecology, with the result that operations were often based on erroneous ideas, with consequent failure. The nightingales, canaries, partridges and pheasants released into the local skies did not last long, nor were introductions of the Murray Cod and the 'Murray lobster' into the Yarra Yarra River a success. The attempt to grow oysters and crayfish in Lake Corangamite because it possessed a salinity similar to that of the ocean reveals the lack



of understanding of the times. However, there were successes such as introductions of the trout, the starling, the thrush, the sparrow, the rabbit and the blackberry. In view of modern experiments, it is interesting to note that Brahmin cows were introduced. Aden, Bengal and Russian sheep were also tried. McCoy, Mueller and other leading scientists of early Victoria took an interest in the work of this society.

Energetic and hopeful though the beginnings of science were in the 1850's, no one dreamed that within a century Melbourne would be a city of over 1,000,000 citizens with very numerous scientific societies.

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### BOOK REVIEW

*Come Wind, Come Weather.* By Mary Howitt Walker. 348 pp. Melbourne University Press, 1971.

This book is the long-awaited first biography of A. W. Howitt, a legendary figure in the exploration, geology, anthropology and natural history of Australia, and particularly of East Gippsland. The title is perhaps unfortunate, since potential readers may miss the allusion to A. W. Howitt in an obscure quotation from Bunyan. The real subject matter is indicated only in a sub-title. The author, who is A. W. Howitt's grand-daughter, has used as source material unpublished letters and diaries which have been in the possession of her family but are now, Mrs. Walker states, deposited in the La Trobe Library, Melbourne.

The first Chapter, which traces the Howitt family from the time of Henry VIII in England, is possibly of family interest but not particularly relevant to the main theme. A. W. Howitt makes his first appearance in Chapter 2, born at Nottingham, England, April 17, 1830 . . . 'pink and white with a head like an egg'. But other and more pertinent pointers to the Howitt of Australia emerge from the story of his early life. His mother and father were both professional writers whose circle of friends included Wordsworth, Dickens, Tennyson. The family pre-occupation with the apt, descriptive word obviously rubbed off on Alfred. His mother, Mary Howitt, was fluent in several foreign languages: later, in Australia, Alfred became fluent in various aboriginal dialects. When the family shifted to London, 1836, young Alfred first showed that 'bent for exploration which took him wandering alone', and was once eventually located in the Zoological Gardens 'in the rhinoceros enclosure'. In 1843 the Howitt family moved briefly to Germany, where Alfred attended school in Heidelberg. His knowledge of the German language, thus early gained, facilitated his later study of microscopic petrology and his communication with the leading German workers of his day, in this field.

In 1852 Alfred's father, William Howitt, decided to make a trip to the goldfields of Australia, and to

take with him his two sons. William's interest was only partly in gold. He was very willing to pick up a fortune on the fields (without too much hard work!) but his real aim was to look at Australia and write about it, and he did this. He returned, after two years, to his literary friends in London. Chapters 3-6 are perhaps the most generally interesting in the book, with many fascinating extracts from letters of both William and Alfred Howitt describing their sea journey, Melbourne as they found it in the early 1850's, and life on the diggings. Alfred writes with a lurking Dickensian sense of fun, and apparently had in mind eventual publication. 'Ask Mr. Cassell,' he wrote to his sister in London, 'what he would give me for a set of sketches to illustrate my letters.' It was at this time, 1855, that he took up sketching. His letters were never published, but his later sketches for his geological reports are well-known.

After his father and brother returned to England, Alfred stayed on, and in Chapters 7 and 8, extracts from his letters to his family give breezy comment on the social life of Melbourne, as well as on his own activities. By 1857 he had definitely decided to stay in Australia . . . 'I am naturally a savage', he wrote . . . 'the bush is my real home'.

In explorations for gold in Victoria and for new pastoral lands in South Australia he proved himself an exceptionally good bushman, with ability to manage successfully in difficult terrain. Because of this, and of his knowledge of the dry interior of South Australia, he was chosen, 1861, to lead the Burke and Wills Relief Expedition, and the second, subsequent expedition for relief of other searching parties. These events are recounted in Chapters 9-12.

The remaining Chapters, 13-20, relate events in Howitt's personal life after his appointment, 1863, as Police Magistrate, Warden, Crown Lands Commissioner and Coroner in Gippsland. These were joint appointments, and Howitt wrote to his sister, 'I feel like a bloated pluralist'. In 1864 he married Maria ('Liney') Boothby, the daughter of an Adelaide judge and a family friend. Her own mother described Liney as a 'simple, retired and affectionate girl', but otherwise we learn little about her, except that it was a happy marriage, productive of five children.

The latter part of the book traces somewhat sketchily Howitt's advances into the fields of geology, anthropology and the natural sciences. Unfortunately it omits an account of his work as Police Magistrate, so perhaps he did not document this. We learn that after a short time in Omeo he was shifted to Bairnsdale where he bought a near-by farm property, Eastwood. 'His life was held fairly in balance between the opposing forces of the Eastwood farm and his duties as magistrate and warden which, between them, provided the family's bread and butter, although he was kept in the saddle for over seven thousand miles a year.'

Howitt's geology was self-taught. He must have learned much from his association with the mining communities; he observed, he collected rock specimens to examine in his rough-and-ready laboratory at Eastwood, and he studied his geology books even in

the saddle. Eventually his knowledge of East Gippsland geology was recognized by the Mines Department and here, as throughout his life, he was fortunate in his connections. He seems to have had an ability to make friends who respected his scholarship. Brough Smyth, the Secretary of the Department of Mines in Victoria, was his 'friend and ally', and his first geological reports were published in *The Gold Fields and Mineral Districts of Victoria*, 1869, which Brough Smyth edited. He became a Fellow of the Geological Society of London, proposed by Professor McCoy, supported by Ulrich and again, Brough Smyth. His sister Mary, in London, to whom he was very closely attached, helped him in many ways also. She sent him books, instruments for his petrological work. She even entertained at her London dinner table people who could further his progress. Such a person was Dawkins, first Professor of Geology at Owens College, afterwards the University of Manchester. 'He is very conceited but really quite intelligent', Mary wrote to her brother, 1869, 'I shall cultivate his acquaintance on your account.' Here it is amusing to note that when Howitt's major paper on the geology of North Gippsland was presented to the Geological Society of London, 1879, Professor Dawkins read it! The considerable significance of Howitt's geological work is admirably summarized in Chapter 21 by Dr. John Talent, himself an authority on Gippsland geology.

In Chapter 22 the same service is done by Dr. John Mulvaney for Howitt's work in anthropology. This assessment is welcome, since Mrs. Walker's account of the anthropological work (Chapters 17, 18) loses the general trend in details of Howitt's agreements and disagreements with other workers.

There are 5 Appendices, 2 of which give bibliographies of Howitt's publications in geology and anthropology, a helpful list of references and a satisfactory index.

The best parts of this book are the direct quotations from Alfred Howitt's own writing, mainly his letters. He had acute powers of observation and ability to translate vision into vivid prose. Even in his old age,

when he delivered the Presidential Address at the AAAS Meeting in Adelaide, 1907, on his reminiscences of Central Australia and the Burke and Wills Expedition, he retained this vitality of expression. He describes the camels forced to cross a flooded creek . . . 'as they waded through the deep mud on the other side, they drew their feet out of it with a sound like drawing a gigantic cork'. On the edge of the Stony Desert . . . 'the landscape could have been painted in sepia and Indian ink'.

From a present day perspective, some of Howitt's fascination is in his emergence as a type specimen of the virile scientist of the nineteenth century. He was a true disciple of Darwin. That he firmly believed in evolution is incidental; more important, he wanted to explore the world he lived in, examine what he discovered with the best scientific techniques he could assemble, build his theories from the collected evidence. Like many others of this time, he was a 'gentleman scientist', academically untrained, not dependent on his scientific work for his livelihood. Yet his contribution to knowledge in his chosen fields was spectacular.

Certainly he came from a sophisticated environment in England, one which recognized the importance of scholarship. But it is still amazing that in the isolated, remote East Gippsland bush, leading a very strenuous life, Howitt accomplished so much intellectually. Did the hitherto undocumented Australian environment present him with a unique chance to become known—as it did, and still does, for other scientific workers? Or was he, as his friend Sir Baldwin Spencer wrote of him, a 'great' man, a unique human being? A future study of A. W. Howitt may attempt to answer these questions; Mrs. Walker's book does not. But it is a pleasant chronicle which, in parts, makes very good reading.

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Junction Buchan and Murendal Rivers, East Gippsland, Victoria. (A. W. Howitt, 1876)



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This should be a concise summary, limited to 250 words, stating the principal results of the research.

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1967 Recent Ostracoda from Port Phillip Bay, Victoria. 80: 61-106 (3 Pl., 10 Fig.).

**McKinty, J. A.**

1969 Forestry in East Gippsland. 82: 129-139 (Fig.).

**McLaughlin, R. J. W.**

1966 Geochemical concentration under saline conditions. 79: 569-577 (2 Fig.).

**McLaughlin, R. J. W., and Macumber, Jennifer J.**

1968 Mineral springs of the Daylesford district. 81: 143-148 (2 Fig.).

**McLennan, E.**

1961 Australian Tuberales. 74: 111-117 (2 Pl.).

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**Mahoney, J. A.** See also Mulvaney, D. J., Lawton, Twidale, Macintosh, Mahoney and Wakefield, 1964.

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**Mallett, C. W.**

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**Manum, S.** See Cookson, I. C., and Manum, 1964.

**Marker, Margaret E.**

1959 Soil erosion in relation to the development of landforms in the Dundas area of Western Victoria, Australia. 71: 125-136 (5 Fig.).

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**Marwick, J.**

1960 A new Pliocene Struthiolariid (Gasteropoda) from Flinders Island, Tasmania. 72: 41-44 (Fig.).

**Massola, A.**

1960 On the Western Australian Kodja. 72: 87-92.

1962 The Aborigines of the Victorian High Plains. 75: 319-325.

1963 The parrying shields of South-east Australia. 76: 227-232 (2 Fig.).

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**Matthaei, Grace**

1969 Alfred William Howitt. The Mueller Memorial Medal. 82: 3-4, 68 (Fig.).

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**Moore, B. R.**

1965 The geology of the Upper Yarra region, Central Victoria. 78: 221-239 (Pl., 8 Fig.).

1965 The structure and stratigraphy of the Siluro-Devonian sediments of the Middle Yarra basin, Central Victoria. 79: 205-213 (2 Fig.).

**Moors, H. T.**

1968 An attempted statistical appraisal of the Graptolite fauna of Willey's Quarry, Victoria, Australia. 81: 137-141 (2 Fig.).

1970 Ordovician graptolites from the Cliefden caves area, Madurama, N.S.W., with a re-appraisal of their stratigraphic significance. 83: 253-287 (5 Fig.).

**Mulvaney, D. J.**

1960 Archaeological excavations at Fromm's Landing on the lower Murray River, South Australia. 72: 53-85 (3 Pl., 7 Fig.).

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- 1963 Petrological and thermo-magnetic observations in Cainozoic basalts from Drouin South, Victoria, Australia. 76: 147-151. (2 Fig.).
- Mushin, Rose, and Smith, H. R.**
- 1962 A disease of Pelargoniums caused by *Xanthomonas pelargonii*. 75: 35-40 (Pl.).
- ## N
- Neboiss, A.**
- 1960 On the family Cupedidae (Coleoptera). 72: 12-20 (2 Pl., Fig.).
- 1967 The genera *Paracalais* gen. nov. and *Austrocalais* gen. nov. (Coleoptera: Elateridae). 80: 259-287 (4 Pl., 49 Fig.).
- Neilson, J. L.**
- 1962 Notes on the geology of the High Plains of Victoria. 75: 277-284 (Fig.).
- Nielsen, Barbara J.**
- 1963 Description of a new species of *Bonellia* (Echiuroidea, Annelida) from Victoria. 76: 61-67 (Pl., 3 Fig.).
- Norman, F. I.**
- 1967 The interaction of plants and animals on Rabbit Island, Wilsons Promontory, Victoria. 80: 193-200 (Pl., 2 Fig.).
- 1970 Ecological effects of rabbit reduction on Rabbit Island, Wilsons Promontory, Victoria. 83: 235-251 (Pl., 10 Fig.).
- 1971 Problems affecting the ecology of islands in the West Gippsland Region. 84: 7-17 (Fig.).
- ## O
- Ollier, C. D., and Joyce, E. B.**
- 1964 Volcanic physiography of the Western Plains of Victoria. 77: 357-376 (4 Pl., 3 Fig.).
- ## P
- Parker, C. D.**
- 1970 Quality of Water. 83: 3-10.
- Parsons, R. F.**
- 1966 The soils and vegetation at Tidal River, Wilsons Promontory. 79: 319-354 (3 Pl., 5 Fig.).
- 1968 An introduction to the regeneration of Mallee eucalypts. 81: 59-68 (3 Fig.).
- Parsons, R. F., and Gill, A. M.**
- 1968 The effects of salt spray on coastal vegetation at Wilsons Promontory, Victoria, Australia. 81: 1-9 (Pl., Fig.).
- Pedder, A. E. H.**
- 1965 A revision of the Australian Devonian corals previously referred to *Mictophyllum*. 78: 201-220 (5 Pl.).
- 1967 *Lyriellasma* and a new related genus of Devonian tetracorals 80: 1-29 (7 Pl., 15 Fig.).
- 1967 Lower Devonian Streptelasmatic, Lindstroemiid and possible Amplexocariniid corals from Victoria. 80: 107-130 (3 Pl., 8 Fig.).
- Pescott, R. T. M.**
- 1961 The Royal Society of Victoria from then, 1854, to now, 1959. 73: 1-40 (Fp., 3 Pl.).
- Peterson, J. A.**
- 1971 The equivocal extent of glaciation in the southeastern uplands of Australia. 84: 207-211 (2 Fig.).
- Philip, G. M.**
- 1962 The palaeontology and stratigraphy of the Siluro-Devonian sediments of the Tyers area, Gippsland, Victoria. 75: 123-246 (26 Pl., 17 Fig.).
- 1963 The tertiary echinoids of South-Eastern Australia. I. Introduction and Cidaridae. 76: 181-226 (6 Pl., 5 Fig.).
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- 1965 The tertiary echinoids of South-Eastern Australia. III Stirodonta, Aulodonta and Camarodonta (1). 78: 181-196 (4 Pl., 4 Fig.).
- 1965 Lower Devonian conodonts from the Tyers area, Gippsland, Victoria. 79: 95-117 (3 Pl., 2 Fig.).
- 1969 The tertiary echinoids of South-Eastern Australia. IV Camarodonta (2). 82: 233-275 (14 Pl., 8 Fig.).
- 1969 Silurian conodonts from the Dirk Hartog formation, Western Australia. 82: 287-297 (2 Pl., Fig.).
- 1971 A re-description of the Tertiary Echinoid genus *Goniosigma* Fell 1964. 84: 227-228 (Pl.).
- Pryor, R. J.** See also Cochrane, G. R., and Pryor, 1964.
- 1967 An evaluation of land development, Flinders Island. 80: 201-209 (Pl., 4 Fig.).
- ## R
- Rawlinson, P. A.**
- 1966 Reptiles of the Victorian Mallee. 79: 605-619.
- 1967 The vertebrate fauna of the Bass Strait islands II. The reptilia of Flinders and King Islands. 80: 211-223. (Part I. Littlejohn and Martin 1965).
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- Ray, L. J.** See Sunderland, S., and Ray 1959.
- Reichl, Phyllis**
- 1971 A brief history of West Gippsland. 84: 1-5.
- Robinson, G.**
- 1966 The regime of Hattah Lakes. 79: 561-568 (Pl., 3 Fig.).
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- 1971 See Bird, E. C. F. and Rosengren, 1971.



## S

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1963 On the tectonic stresses in the vicinity of a valley and a mountain range. 76: 141-145 (2 Fig.).
- Schleiger, N. W.**  
1969 Problems in sampling the orientation of fossils in a graptolite band at Eaglehawk, Victoria. 82: 161-177 (2 Pl., 10 Fig.).
- Shergold, J. H.**  
1968 On the occurrence of the Trilobite genera *Acaste* and *Acastella* in Victoria. 81: 19-30 (3 Pl.).
- Sherrard, Kathleen**  
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- Stewart, A. J.**  
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- Stinton, F. C.**  
1963 Further studies of the Tertiary oolites of Victoria. 76: 13-22 (3 Fig.).
- Stone, Ilma G.**  
1961 The highly refractive *Protonema* of *Mittenia Plumula* (Mitt.) Lindb. (Mitteniaceae). 74: 119-124 (20 Fig., 3 Pl.).
- Strusz, D. L.**  
1968 On *Cyathophyllum mausfeldense* Dun 1898: Lower Devonian, Loyola, Victoria. 81: 11-17 (Pl., 2 Fig.).
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1959 A note on the Murray Black collection of Australian aboriginal skeletons. 71: 45-48 (2 Pl., 2 Fig.).
- Sutherland, F. L.**  
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- 1965 Geomorphic forms and processes in the highlands of Eastern Victoria. 78: 119-135 (7 Pl., 4 Fig.).
- 1965 The stratigraphic and diastrophic evolution of Central and Eastern Victoria in Middle Palaeozoic times. 79: 179-195 (2 Fig.).
- 1965 A new species of Conchostrachan from the Lower Cretaceous of Victoria. 79: 197-203 (Pl., Fig.).
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1963 The Devonian-Carboniferous fauna of the Silverband formation, Victoria. 76: 1-11 (2 Pl., 4 Fig.).
- Taylor, D. J.**  
1964 Foraminifera and the stratigraphy of the Western Victorian Cretaceous sediments. 77: 535-603 (8 Pl., 7 Fig.).  
1965 Preservation, composition and significance of Victorian Lower Tertiary 'Cyclammina faunas'. 78: 143-160 (5 Fig.).
- Tex, E. den**  
1959 The Geology of the Grey Mare range in the Snowy Mountains of New South Wales. 71: 1-24 (3 Pl., 5 Fig., Map).

**Thomas, G. A.**

- 1965 An echinoid from the Lower Carboniferous of North-West Australia. 79: 175-178 (Pl., Fig.).

**Thomson, D. F., and Hosmer, W.**

- 1963 A preliminary account of the herpetology of the Great Sandy Desert of Central Western Australia. Reptiles and amphibians of the Bindibu expedition. 77: 217-237 (4 Pl., Fig.).

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- 1963 Victorian species of *Gleichenia* Smith (subgenus *Mertensia*) 76: 153-162 (Pl., 3 Fig.).

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- 1962 The dune succession at Corner Inlet, Victoria. 75: 17-33 (2 Pl., 3 Fig.).

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**Valentine, J. W.**

- 1965 Quaternary mollusca from Port Fairy, Victoria, Australia, and their palaeoecologic implications. 78: 15-73 (6 Pl., 8 Fig.).

**Verso, M. L.**

- 1965 A study of blood cell agglutinins in plant extracts. 78: 167-173.

## W

**Wadc, Mary**

- 1971 Bilateral Precambrian Chondrophores from the Ediacara Fauna, South Australia. 84: 183-188 (Pl., Fig.).

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- 1964 Recent mammalian sub-fossils of the Basalt Plains of Victoria. 77: 419-425 (Map).
- 1966 Mammals of the Blandowski expedition to North-Western Victoria, 1856-57. 79: 371-391 (Fig.).
- 1966 Mammals recorded for the Mallee, Victoria. 79: 627-636 (Fig.).
- 1969 Aspects of exploration and settlement of East Gippsland. 82: 7-25 (3 Fig.).
- 1969 Botanical exploration of East Gippsland. 82: 61-67.
- Waldman, M.**
- 1971 A re-examination of *Psilichthys selwyni* Hall, from the Lower Cretaceous of Victoria. 84: 263-266 (3 Pl.).
- Waldman, M., and Handby, P. L.**
- 1968 Tertiary fish from Morwell, Victoria. 81: 95-96. (Fig.).
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- 1965 Description of a fossil humerus (Marsupialia) from the Lower Pliocene of Victoria, Australia. 79: 147-151 (Pl., Fig.).
- Wharton, J. C.**
- 1970 Recreation and conservation in the aquatic environment. 83: 47-54 (2 Maps).
- Wilkins, R. W. T.**
- 1963 Relationships between the Mitchellian, Cheltenhamian and Kalimnan stages in the Australian Tertiary. 76: 39-59 (2 Fig.).
- Wiley, E. C.**
- 1970 Lower Devonian Ostracodes: revision of species described by Chapman (1904) from the Lilydale limestone, Victoria. 83: 121-136 (3 Pl., 3 Fig.).
- Williams, G. E.**
- 1964 The geology of the Kinglake district, Central Victoria. 77: 273-327 (5 Pl., 13 Fig.).
- Williams, W. D.**
- 1970 Eutrophication of lakes. 83: 17-26 (Pl.).
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- 1961 Botanical science in Victoria 100 years ago. 73: 41-45.
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- 1962 **The Victorian High Plains Symposium.** (held 14 Sept., 1961).  
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- 1967 **East Gippsland Symposium.** (held 14 Sept., 1967).  
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- 1969 **The Aquatic Environment and Man.** (held 13 June 1968)  
Foreword. 7 papers by Parker, C. D.; Bayly, I. A. E.; Williams, W. D.; Horsfall, R. A.; Callinan, B. J., Garland, K. R.; Wharton, J. C. 83: 1-54.
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BACHER G.J. BSC,44 MARIANA AVE,CROYDON,VIC 3136	1968
BACKHOUSE, R.A. BSC,OIP,ED,69 FLOWER STREFT,NUNDAH,QLO 4012	1962
BAILLIE MRS,J LLR BA ALAA,MOUNT VIEW RO.,TEMPLESTOWE,VIC 3106	1968
BAIN, DR. A. O. N. OSC FGS,19 ALBERT RO.,CAVERSHAM, BERKSHIRE, ENGLAND	1950
BARKER, H.E.R. BSC PHC FPS FRACI,4 HILLCREST AVE.,KEW,VIC. 3101	1957
BARNES C.P. BSC,MINES DEPT.,107 RUSSELL ST.,MELBDURNE, VIC 3000	1968
BARTLETT, A.H. BSC,3B KENT AVF.,CROYDON,VIC. 3136	1952
BARTRAM, DR. R.D. MC BA MBBS,222 CANTERBURY RO.,CANTERBURY, VIC. 3126	1958
BASSETT, SIR WALTER MC MMECHE BEE,133 KDOYDNG RO.,ARMADALE, VIC. 3143	1957
BATE, D.E. BSCENG,THDNEMANS RO.,HODDLES CREEK,VIC. 3139	1954
BEADNELL, DR. L.M.M. MRCS LRCP FRGS,23 ANOERSON ST.,EAST MALVERN, VIC. 3145	1959
BEASLEY, OR. A.W. MSC PHD DIC FGS,NATIDNAL MUSEUM, RUSSELL ST.,, MELBOURNE,VIC. 3000	1950
BEAUGLEHOLE, A.C.,3 BEVERLEY ST.,PORTLAND,VIC. 3305	1965
BEAVIS, DR. F.C. BSC PHD,GEOLOGY OEPT., MELB UNIV,PARKVILLE, VIC. 3052	1957
BECHERVAISE J.M. MBE FRSA FRGS,185 ROSLYN RD.,BELMONT,VIC 3216	1968
BELL, K. BSC,45 WAITARA GROVE,NORLANE,VIC 3214	1961
BENFEDEK, S. RGEOL BUDAPEST,2 HILLTOP CRESCENT,EAST BURWOOD, VIC 3151	1963
BENNETT, D.H. AMIREF,10 CAMPBELL ST.,BRIGHTON,VIC. 3186	1968
BENTLEY, DR. G.A. MSC PHD,28 WRIGHT ST.,BENTLEIGH,VIC. 3204	1959
BIRD, OR. E.C.F. MSC PHD,GEOGRAPHY OEPT., MELB, UNIV,PARKVILLE, VIC. 3052	1961
BLACKBURN, J.A.D.,4 MCHALE COURT,ESSENOON,VIC. 3040	1966
BLACKWOOD, SIR ROBERT MCE BEE MIE,8 HUNTINGFIELD RD.,BRIGHTON, VIC. 3186	1957
BOND H.W. B.SC,FOR.,301 PROSPECT ST., NEW HAVEN,CONNECTICUT, U.S.A. 06520	1970
BORBIDGE R.T.,4/277 DANDENONG RD.,WINDSOR,VIC 3181	1968
BOYD ROBIN FRAIA HFAIA D.LITT,340 ALBERT STREET,EAST MELBDURNE, VIC 3002	1968
BRACK, L.J. BCE,B TOWER ST.,HAWTHORN,VIC. 3122	1960
BRADLEY K,LOT 16,GRAYLIND AVE.,WEST PENNANT HILLS,NSW 2120	1968
BRAITHWAITE, H.A. PHC FPS,8 KASOUKA RO.,CAMBERWELL,VIC. 3124	1958
BRAY, R. MPS FBQA FRSH,27 CDBDEN CRESCENT,LILYDALE,VIC 3140	1965
BRENNAN, D.J.,'EOELWEISS',RUANGDR,VIC. 3375	1963
BRENTON, W.G. BSC DIPED,BOX 579 P.D.,GEELONG,VIC. 3220	1963
BRETT, DR. H.W.W. BSC PHD CANTAB,100 FAWKNER ST.,ESSENDON,VIC 3040	1965
BRINE F. W.,TAUNTON OAKDENE CDURT,MOUNT WAVERLEY,VIC 3149	1964
BRINER, DR. G.P. MSC PHO,OEPT.AGRICULTURE CHEM,LABS, 5 PARLIAMENT PLACE MELBDURNE, VIC 3002	1963
BRDADHURST, E. MSC,8/130 BALWYN ROAD,BALWYN,VIC 3103	1930
BRDWN DR. A.G. BA CANTAB MRCS ENG LRCP LOND MIBIOL,'NARRDGHIT', ELLIMINYT,COLAC,VIC. 3250	1958
BROWN M. LLB,A.A.S. COLLEGE KUNYUNG RD.,MT. ELIZA,VIC 3930	1968
BROWN PROFESSOR R.D. MSC, PHD.,21 BROLGA ST.,MOUNT WAVERLEY, VIC. 3149	1960



BRUNNSCHWEILER OR. R.O. PHO ZURICH, RES. REP. U.N. DEVEL. PROG, NIGER, P.O. 256, NIAMEY, REPUBLIQUE DU NIGER,	1959
BRYANT R.L., PHYSICS DEPT MONASH UNI., P.O. BOX 92 CLAYTON, VIC 3168	1964
BUCHANAN R.A. BAGRSC MS PHD LONDON, 5 WAMBA ROAD, EAST BENTLEIGH, VIC 3165	1968
BUNTINE J.O. M.SC. OIP, ED. AAIP, 15 SUNHILL AVENUE, RINGWOOD, VIC 3134	1970
BURNET PROF. SIR MACFARLANE OM HO PHD SCO OSC FRACP FR3 FAA, MELBOURNE UNIVERSITY, PARKVILLE, VIC 3052	1959
BUTCHER, A. OUNBAVIN MSC, FISHERIES AND WILDLIFE DEPT., 805 FLINDERS ST. MELBOURNE, VIC. 3200	1936
BYRNE J.H. PHC, FPS, 11 MITCHELL RD., CAULFIELD, VIC 3162	1963
CAMPBELL OR. A.M. MD, BS, FRACP, 105 BANKSIA ST., HEIDELBERG, VIC 3084	1965
CAMPBELL F.J.S. FAIA, 8 BENWERRIN RD., MONT ALBERT, VIC 3127	1968
CAMPBELL DR. K.S.W. MSC. PHO., GEOL DEPT AUST NATIONAL UNI., BOX 4 G.P.O. CANBERRA, ACT 2600	1964
CANAVAN F. HSC, 26 STANHOPE GROVE, CAMBERWELL, VIC 3124	1936
CANDLER C. HA (CANTAB), 7A HONEY SUCKLE ST., BENDIGO, VIC. 3550	1964
CANNY PROF. M.J. HA PHO (CANTAB), BOTANY DEPARTMENT, MONASH UNI., CLAYTON, VIC. 3168	1965
CARO, PROF. O.F. MSC PHD, DEPT. OF PHYSICS, MELB. UNI. PARKVILLE, VIC. 3052	1961
CARR, PROFESSOR D.J. MSC PHD, DEPT. DEVELOPMENTAL BIOLOGY, A.N.U. P.O. BOX 4, CANBERRA, ACT. 2600	1957
CARTER A.V. 10 AYR RD., OONCASTER, VIC 3108	1968
CASEY, D.A. MC FSA, 'WILLIMUI', CHENISTON RD., MT MACEDON, VIC. 3441	1932
CASSON, J. OBE, 2 MATHOURA RD., TOORAK, VIC. 3142	1965
CHINNER, J.H. BSC OXON MELB DIPFOR, FORESTRY SCHOOL MELB. UNI., PARKVILLE, VIC. 3052	1950
CHIPMAN, H.C. ISO LLB, 35 SPENCER ST., ESSENDON, VIC. 3040	1958
CHRISTOPHERS DR. B.E. MB BS BSC, 366 CHURCH STREET, RICHMOND, VIC 3121	1969
CHURCHILL DR. D.M. BSC HA PHD, BOTANY DEPT MONASH UNI, CLAYTON, VIC 3168	1968
CLARK SIR LINDESAY CMG MC BSC DENG MHE, WESTERN MINING CORP. LTD., 360 COLLINS ST., MELBOURNE, VIC. 3000	1931
COLLINS A.C., 90 WARWICK STREET, NEWTOWN, GEELONG, VIC 3220	1928
CONNELL J.W. F. INST STRUCT. E, 531 THE BOULEVARD, EAST IVANHOE, VIC 3079	1970
CONROY, T.M. ASASM FRACI, 1 EDWARD ST, KEW, VIC 3101	1965
CORBY W.P., 11 AISBETT AVENUE, BURWOOD, VIC 3125	1969
COSTERHANS L.F. BSC, ALEXANDRA HIGH SCHOOL, ALEXANDRA, VIC 3714	1968
COUTTS P.J.F. MSC BEE, ANTHROPOLOGY DEPT., UNIV. OF OTAGO, DUNEDIN, NZ	1965
COWLEY PROF. J.M. PHD DSC FAA, DEPT. OF PHYSICS, ARIZONA STATE UNIV., TEMPE, ARIZONA, USA	1963
COWLING, S.J. BSC FOR, 16 GLOUCESTER DRIVE, HEIDELBERG, VIC 3084	1965
CRICHTON, G.A., 6 AINSLEY PARK AVE., CROYDON, VIC 3136	1968
CROOK, DR. K.A.W. MSC PHD, GEOLOGY DEPARTMENT, A.N. UNI. BOX 4, GPO CANBERRA, A.C.T. 2600	1964
CROPLEY F.W. BE DIP. EE FSASMI, 7 OLAN AVENUE, HAWTHORN, VIC 3122	1969
CROW, R.K. JP SMIRE, 20 PARKER STREET, ORMOND, VIC 3204	1958
CULKA J.O. INGCHER PRAGUE, 12 NURLENDI RD, VERMONT, VIC 3133	1968
CUHING, DR. B.D. PHD, GROVE ST., VERMONT, VIC. 3133	1959
CUHING, M.A. BSC DIC FRACI, 401 COLLINS ST., MELBOURNE, VIC 3000	1958
CUMING W.R. BE MECH GRAD. I.E. AUST., 9 LAUGHING WATERS RD., ELTHAM, VIC 3095	1968
CUMMING PROF. R.W. BE (AERO). ME. AM (PSYCH), HOWITT HALL, MONASH UNIV., CLAYTON, VIC 3168	1970
CUHMINS J.E. M.SC. FRIC, FRACI, 10 MORTIMER ST., KEW, VIC 3101	1969
CURPHEY A.N. OBE, FSS, ENG, 25 KEAM STREET, EAST IVANHOE, VIC 3079	1958
CURREY, D.T. BSC, 61 SYLVANDER ST., NORTH BALWYN, VIC. 3104	1948
CURRY J.L. B.COM, 88A FISHER ST., FULLARTON, S.A. 5063	1969
OARRAGH, T.A., 46 ESPLANADE, CLIFTON HILL, VIC. 3068	1963
DARVALL OR. P. LE P. HA HS MSC PHD, 56 THE EYRIE, EAGLEMONT, VIC 3084	1970
DAVIE R.S. BE MECH MIE AUST MACE, 26 ELIZABETH ST., EAST BRIGHTON, VIC 3187	1970
DAY, P.L. BSC, 1 KINGSLEY COURT, BALLARAT, VIC 3350	1962
DEHPSTER, J.K. BSC, 76 ILLAWARRA RD., HAWTHORN, VIC. 3122	1967
DERHAM, MRS. F.T. BAGRSC HSC LONDON, 97 ROYAL PARADE, PARKVILLE, VIC. 3052	1959
DIXON, HISS J.M. BSC HONS, NATIONAL MUSEUM OF VICTORIA, MELBOURNE, VIC. 3000	1965

OOBROTHDRSKY DR. N. MSC PHD, DEPT. OF ZOOLOGY, UNIV. OF MELBOURNE PARKVILLE, VIC 3052	1967
OOERY, MISS M.K. BSC OIPEO, 20 TOWER ST., MONT ALBERT, VIC. 3127	1964
OORMAN, DR. F.M. MA MSC PHD, 4 JOSEPH ST., LOWER TEMPLESTONE, VIC. 3107	1958
OORWARD, DR. O.F. BSC OPHIL, DEPARTMENT OF ZOOLOGY, MONASH UNIVERSITY, CLAYTON, VIC. 3168	1964
DOUGLAS, G.W. B AGR SC, 36 INVERNESS WAY, NORTH BALWYN, VIC 3104	1960
DOUGLAS, DR. J.G. MSC PHD, 76 SUNHILL RD., MT. WAVERLEY, VIC. 3149	1957
DOUGLAS N., BEND OF ISLANDS, KANGAROO GROUNDS, VIC 3097	1968
DOWN, MRS. M.R. BAGRSC, 177 COPELAND RD., EAST, BEECROFT, N.S.W. 2119	1942
DOWNES, R.G. MAGRSC FAIAS, SOIL CONSERVATION AUTHORITY, 378 COTHAM RD., KEW, VIC. 3101	1961
DOWNING DR. H.J. MAGRSC PHD BEO MACE MAIAS, C/O 34 NEWTON ST., RESERVOIR, VIC 3073	1968
DRUMMOND, DR. F.H. BSC PHD, ZOOLOGY DEPT., MELB. UNIV., PARKVILLE, VIC. 3052	1933
DRUMMOND MRS. M.M. MSC, 68 MONT ALBERT RD., CANTERBURY, VIC 3126	1968
DUCKER, MRS. S.C. MSC, BOTANY DEPT., MELB. UNIV., PARKVILLE, VIC. 3052	1959
DUIGAN, DR. SUZANNE L. MSC PHD, BOTANY DEPT., MELB. UNIV., PARKVILLE, VIC. 3052	1960
DUKE, J.R. BSC, 7 ESSON ST., SHEPPARTON, VIC. 3630	1961
DUNCAN, P.M., 25 ORION STREET, NORTH BALWYN, VIC 3104	1966
DUNGAN, DR. R.W. MB BS, 117 MILLSWYN ST., SOUTH YARRA, VIC. 3141	1958
DUNN, R.A. AAA AAIS, 67 MIMOSA RD., CARNEGIE, VIC. 3163	1946
DYASON, MISS D.J. MSC, MELBOURNE UNIV., PARKVILLE, VIC. 3052	1960
EALFY, DR. E.H.M. MSC PHD, MONASH UNIVERSITY, CLAYTON, VIC. 3168	1961
EARL, C.T. BCE AMIE AUST, 46 SCOTT ST., ESSENDON, VIC 3040	1961
EODY, A.R. BSC MP A.OIP, FOR, MIFA, VICTORIAN SCHOOL OF FORESTRY, CRESWICK, VIC 3363	1963
ELLIOTT W.W. MA BSC, 3 BALWYN ROAD, CANTERBURY, VIC 3126	1968
ETTERS HANK, DR. G MSC PHD (CORNELL), DEPT. OF ZOOLOGY, MONASH UNIVERSITY, CLAYTON, VIC. 3168	1965
EVANS E.H. FAI, 153 SUMMERHILL RD, GLEN IRIS, VIC 3146	1968
EVANS, W.P., 8 ANZAC CRESCENT, WILLIAMSTOWN, VIC 3016	1968
FALK MRS. B MA MELB DIPED OXDN, CENTRE FOR STUDY HIGHER EDUC, MELBOURNE UNI PARKVILLE, VIC 3052	1968
FARRER, DR. K.T.H. OSC FRIC FRACI, 40 GLEN EBOR AVE., BLACKBURN, VIC. 3130	1966
FEARN-WANNAN, H.J. MSC BEO MACE, 2 MERLE ST, NORTH BLACKBURN, VIC. 3130	1958
FENSHAM, PROFESSOR P.J. MSC PHD ARACI, FACULTY OF EDUCATION, MONASH UNIV CLAYTON, VIC 3168	1967
FERRER O.I. BA BSC, MOBIL OIL AUST LTD, 2 CITY RD. MELBOURNE, VIC 3000	1968
FERRIER, J.MCN, P.O. BOX 20, COLERAIN, VIC. 3315	1960
FOCKEN, DR. C.M. BSC BME OPHIL, OXON MS COLORADO, 20 CARSON ST., KEW, VIC. 3101	1952
FORSTER MRS. P.G., 14 MAPLE CRESCENT, CAMBERWELL, VIC 3124	1970
FOSTER, DR. R.C. BSC PHD, FLAT 7, 423 BRUNSWICK RD., WEST BRUNSWICK, VIC 3056	1967
FRANKENBERG R.S. BSC, WARRANGEE, HOWLONG, NSW 2640	1967
FREAKE, R., 117 MILLSWYN ST., SOUTH YARRA, VIC. 3141	1961
FRY, DR. E. BOSC OOSC MUENSTER, 67 WILLIAMS RD., WINDSOR, VIC. 3181	1961
GALLUS, DR. A. PHD BUOPEST OJUR SZEGED, 2 PATTERSON ST., NUNAWADING, VIC 3131	1963
GARNET, J.ROS, 23 CAMOON ST., PASCOE VALE, VIC. 3044	1965
GARRATT M.J. BSC FGS, SCHOOL OF EARTH SCIENCES, MACQUARIE UNIV NORTH RYDE, NSW 2113	1969
GARRETT B.K., FLAT 2, 28 FULTON ST, EAST ST. KILOA, VIC 3183	1965
GARTSIOF O.F. BSC, ZOOLOGY DEPT MELBOURNE UNI, PARKVILLE, VIC 3052	1968
GASKIN, A.J. MSC, 6 BURNS ST., ELWOOD, VIC. 3184	1941
GEORGE, A.M. BSC, 15A KYEAMBA GROVE, TOORAK, VIC. 3142	1963
GERRATY DR. N.L. BSC BVSC OIP, EO, 59 ATHELSTAN ROAD, CAMBERWELL, VIC 3124	1969
GIBBONS, F.R. BSC, 'SHERBURN' ARUNOEL RD., PARK ORCHARDS, VIC. 3114	1963
GIBBS, DR. W. MSC MS MIT, BUREAU OF METEOROLOGY, 2 DRUMMOND ST. CARLTON, VIC. 3053	1963



GILL, E.D. BA BD FGS FRGS, NATIONAL MUSEUM OF VICTORIA, 285 RUSSELL ST., MELBOURNE, VIC 3000	1938
GILMOUR DR. A.H. PHD BSC, FISHERIES & WILDLIFE DEPT., 605 FLINDERS ST., MELBOURNE, VIC 3000	1968
GLEN DR. J.B. BSC PHD, FLAT 4 70 NIRVANA AVE, EAST MALVERN, VIC 3145	1968
GLOE, C. MSC, 23 KIRKWOOD ST., BEAUMARIS, VIC, 3193	1944
GOODE, D.W., 3 MANDEVILLE CRESCENT, TOORAK, VIC, 3142	1968
GORDON, A. BSC, MARLBOROUGH ST., MONT ALBERT, VIC, 3127	1961
GOTTLIEB, L. DIPMECH HAMBURG, 17 LAVER ST., KEW, VIC, 3101	1958
GOUDIE, A.G. BAGRSC, MURCHISON RD., TATURA, VIC, 3616	1941
GRANT, K. BSC, 6 BOYLE STREET, FOREST HILL, VIC 3131	1962
GRIFFITHS DR. A.F. MB BS, 1451 BURKE RD, NORTH, EAST KEW, VIC 3102	1961
GROSE, DR. R.J. RSC FOR OIPFOR AMIFA, FORESTS COMMISSION, TREASURY PLACE, MELBOURNE, VIC 3002	1960
GROUNDS SIR, ROY KRE B. ARCH FRAIA FRVIA, 549 ST, KILDA ROAD, MELBOURNE, VIC, 3004	1958
GRUBB, DR. P.L.C. BSC PHD, CSIRO MINERAGRAPHIC INVEST., UNIV. OF MELBOURNE, PARKVILLE, VIC 3052	1964
GUNSON DR. H.M. MSC, PHD, 23 BALWYN ROAD, CANTERBURY, VIC 3126	1944
HACK, J.B. BSC, 414 COLLINS ST., MELBOURNE, VIC, 3000	1957
HANCOCK, J.S. BSC, FLAT 4, 80 MATHOURA RD., TORAK, VIC, 3142	1965
HANDBY, P.L., 34 AVONDALE CRESCENT, MORWELL, VIC, 3840	1966
HARGREAVES G.R. BSC DIP. ED, SECONDARY TEACHERS COLLEGE, SWANSTON ST. PARKVILLE, VIC 3052	1969
HARRIS, I.C. A.DIP. FOR, 1355 GREGORY STREET, BALLARAT, VIC 3350	1967
HARRISON, M. OBE, 3 CHARLES ST., KEW, VIC, 3101	1964
HARTUNG, PROF. E.J. DSC PHD, LAVENOIR FARM, WOODEND, VIC, 3442	1923
HARVEY R.J.D. BA, 28 GREY ST., BALWYN, VIC 3103	1969
HAYYATT MRS. J.U., FLAT 18 75 QUEENS RD., MELBOURNE, VIC 3004	1968
HAWKINS, I.E., 68 LLOYD ST., STRATHMORE, VIC, 3041	1966
HAYDEN MRS. ELIZABETH BSC, 17 MALARA STREET, WARAMANGA, ACT 2611	1967
HAYES A.B. DIPCHEMENG ASTC ARACI AMIEA, 53 LANSDOWNE ST., NORTH BALWYN, VIC 3104	1968
HEAD, W.C.E. BA DIPED, P.O. BOX 127, NUMURKAH, VIC, 3636	1931
HESSLSCHWERDT R.E. BA, 27 HOPETOUN GROVE, IVANHOE, VIC 3079	1969
HIBBERD A.R. PHC FPS MRSH, 50 VICTORIA CRESCENT, MONT ALBERT, 3127	1968
HILLEBRAND P.W. TPIC, C/D K. WARNE-LESTER, 188 TORONGA RD., GLEN IRIS, VIC 3146	1968
HIRD, B.J.W. DIP CIVENG, 15 FORSTER ST., MITCHAM, VIC, 3132	1963
HITDUN G. BA, FLAT 2, 313A DANDENDONG RD, ARMADALE, VIC 3143	1969
HOGAN, T.W. MAGRSC, 100 RIVERSDALE RD., HAWTHORN, VIC, 3122	1947
HOLBEACH, P.W. BAGRSC, 435 WATLETREE RD., EAST MALVERN, VIC, 3145	1967
HOLDWAY PROF. E.A. BSC, M. ED, PHD, C/O DEPT. EDUCATION ADMIN., UNIV. OF ALBERTA, EDMONTON, ALBERTA, CANADA	1957
HOLLAND R.A., FLAT 1, 126 ALBERT ST, EAST MELBOURNE, VIC 3002	1931
HOLLOWAY R.G., BDX B, BEVERFORD, VIC 3590	1969
HOLMES, A.J. BSC BEO, 7 COLLETT AVE., RINGWOOD, VIC, 3134	1949
HOPE, G. BSC, C/O DEPT. BIOGEOG., SCH. PACIFIC STUD., ANU, BOX 4, CANNBERRA ACT 2600	1961
HOSKING, DR. C.G.S. MB BS, STATION ST., YEA, VIC, 3717	1966
HOWARD, J.A. BSC (WALES) MFOR (MINN) DIPFOR FLS, SCHOOL OF FORESTRY, UNIV. OF MELB., PARKVILLE, VIC, 3052	1965
JACK, J.B. BSC FOR AOIPFOR, 9 GLENDALE RD., SURREY HILLS, VIC, 3127	1967
JACKSON MRS. VANDA R.G. B.SC., 14 VICTORY BOULEVARD, ASHBURTON, VIC 3147	1969
JACKSON W.A. ARPS, ARMIT, FIPT, 16 WILSON STREET, CHELTENHAM, VIC 3192	1969
JACOBSON G. BSC, GEOLOGICAL SURVEY OFFICE, KOTA KINABALU, SABAH MALAYSIA	1968
JEFFREYS, R.B. BSC FRACI, 3 ULTIMO COURT, TOORAK, VIC, 3142	1961
JENKIN, DR. J.J. MSC PHD, 28 KERR ST., BLACKBURN, VIC, 3130	1945
JENKINS, R.J., 16 SOMERS ST., NORTH BRIGHTON, S.A. 5048	1968
JENSZ, R.L. BSC, 1 BANDJALONG CRES., ARANDA, ACT 2614	1961
JOBLING, W.J. BSC, 25 CLONMORE ST., BEAUMARIS, VIC, 3193	1965
JOHNSON, T.J.P. BA DIPED, PRIVATE BAG 29, HAMILTON, VIC, 3300	1964
JOHNSTON DR. J.J. MB, BS, 760 STATION ST., BOXHILL, VIC 3128	1969
JONES, K.A. BCDM, 28 SCOTT ST., BEAUMARIS, VIC, 3193	1956
JONES, DR. L.H.P. B AGRSC MSC PHD, GRASSLAND RES. INST., HURLEY, HAIDENHEAD NR., BERKSHIRE, ENGLAND	1948
JONES, N.L., 7 KINGSTON ST., HAMPTON, VIC, 3188	1963
JONES, DR. R. PHD, BOTANY DEPARTMENT, UNIV OF TASMANIA HOBART, TAS 7001	1967



JOYCE, E.B. BSC, GEOLOGY DEPT, MELB. UNI., PARKVILLE, VIC. 3052	1963
KAUFMANN, G.A. BA, FLAT 20, 28 WATTLE RD., HAWTHORN, VIC. 3122	1938
KELLS O.S. B.AGR, SC, DIP. EO, 41 OXFORD ST., BURWOOD, VIC 3125	1969
KEMPSON, F.A. SMIRE, 14 ORUMMOND ST., BLACKBURN SOUTH, VIC. 3130	1938
KENT F.C. B.COM., 123 CHARMAN ROAD, MENTONE, VIC 3194	1970
KIOO G.P. BE BSC, FLAT 22 47 HANOVER ST., FITZROY, VIC 3065	1966
KIMPTON W.S. BE MELB, 11 HENDERSON AVE, MALVERN, VIC 3114	1966
KING G., ORYSDALE RD., WARRANOEY, VIC 3113	1968
KINGSLEY H.P., FLAT 5, 8 POWER STREET, TOORAK, VIC 3142	1969
KITCH R.B. OIP, APP, GEOL., 31 BARRY STREET, BENDIGO, VIC 3550	1970
KLARIC, R., 10 LWR HEIDELBERG RD., IVANHOE, VIC. 3079	1964
KLODT, N.H. MSC, 636 GILBERT RD., RESERVOIR, VIC. 3073	1964
KNIGHT, J.L., 72 STRATHALLAN RD., MACLEOD, VIC. 3085	1944
LABY DR. R.H. MBE, MSC, PHD, 11 LEOPOLD STREET, BURWOOD, VIC 3125	1969
LANG, DR. P.S. BAGRSC PHD, ITITANGA, LISMORE, VIC 3324	1938
LANGOON, C.C., 411 BEACH RD., BEAUMARIS, VIC. 3193	1954
LARKMAN, B.H., 42 ABBEY WALK, VERMONT, VIC. 3133	1967
LAW, DR. P.G. CBE DAPPSC MSC FAIP, VICTORIA INST. OF COLLEGES, 258 LT. BOURKE ST., MELBOURNE, VIC 3000	1946
LAWRENCE A.J. B.SC ARACI, 8 CHARLTON RD., EAGLEMONT, VIC 3084	1969
LEE, F.M. BCE MIE AUST., 51 SEVERN STREET, CHRISTCHURCH NEW ZEALAND	1958
LEE, H.M. MRS. MSC, 54 FITZGIBBON ST., PARKVILLE, VIC. 3052	1957
LEESON DR. L.E. B.AGR, SC, MSC, PHO HARVARD, 7 TAGELL STREET, RINGWOOD EAST, VIC. 3135	1968
LESLIE, A.J. A.OIP, FDR, B.AGR, SC, VIA LUIGI LILIO 62, LAURENTINA 00147, ROME, ITALY	1958
LE SOUEF J.C., GDOFREY ST., BLAIRGOWRIE, VIC 3942	1969
LEY, J.B.K. BCE AMICE, 30 COSHAM ST., BRIGHTON, VIC. 3186	1958
LIDDY, J.C. BSC, 353 CANNING ST., N. CARLTON, VIC. 3054	1959
LINK, A.G., DEPT. OF GEOLOGY, RMIT LONSDALE ST. MELBOURNE, VIC 3000	1963
LINONER, A.W. MSC, C/O S. PACIFIC PETROLEUM NL, GPO BOX 4024, SYDNEY, N.S.W. 2001	1959
LITTLEJOHN, DR. M.J. PHD, DEPT. OF ZOOLOGY, UNIV. OF MELBOURNE, PARKVILLE, VIC 3052	1968
LONIE F.H. LLB, 339 COLLINS ST., MELBOURNE, VIC 3000	1969
LONSDALE A.J. B.SC, B.EO, C/O W.A. INST. TECH., HAYMAN RD., S. BENTLEY, W.A. 6102	1969
LOVERING PROF. J.F. M.SC, PH.D, UNIVERSITY OF MELBOURNE, PARKVILLE, VIC 3052	1969
MACCALLUM PROF. SIR PETER MC MA MSC MB CHB OPH, 91 PRINCESS ST., KEW, VIC. 3101	1925
MACKNIGHT OAME ELLA OBE, MBBS, MO, FRCOG, 12 COLLINS ST., MELBOURNE, VIC 3000	1969
MACRAE C.C.F., 2 POINT AVENUE, BEAUMARIS, VIC 3193	1970
MACROBERT CAPTAIN I. ARINA, 4 SPICER STREET, BEAUMARIS, VIC 3193	1970
MACUMBER, P.G. BSC, 20 RANGEVIEW ROAD, MITCHAM, VIC 3132	1965
MALCOLMSON R.O. MBE BSC AINSP, 250 DRRONG ROAD, TOORAK, VIC 3142	1968
MANDEL DR. T. MB, B9, 37 CLIVEJAY ST., MOUNT WAVERLEY, VIC 3149	1968
MANNING N.C. BSC PHC FPS, COLLEGE OF PHARMACY, ROYAL PARADE, PARKVILLE, VIC. 3052	1960
MARRIOTT F.A., FLAT 112, 333 BEACONSFIELD POE, ST. KILOA, VIC 3182	1968
MARTIN MRS. A.M. MSC, C/O ICIANZ LTD, NEWSOM ST., ASCOT VALE, VIC 3032	1968
MARTIN G. B.Arch, 1 OXFORD COURT, IVANHOE, VIC 3079	1968
MARTIN, M.J., 3 CDDBA ST., CANTERBURY, VIC. 3126	1957
MASUR J. O.D.S.C., 12 CHERRY STREET, GLEN WAVERLEY, VIC 3150	1970
MATHEWS, A.G. BSC, 58 GARTON ST., NORTH CARLTON, VIC. 3054	1961
MATHEWS R.T. MSC, GEOLOGY DEPARTMENT, UNI. OF MELBOURNE, PARKVILLE, VIC 3052	1965
MCANDREW DR. J. BSC PHD, CSIRO MINERAGRAPHIC INVEST., UNIV. OF MELBOURNE, PARKVILLE, VIC 3052	1953
MCCAUSLAND M.E.R., FLAT 4, 9 MONDMEATH AVE, TOORAK, VIC 3142	1953
MCCAUGHEY THE REV. DR. J.D. MA. DO., ORMOND COLLEGE, PARKVILLE, VIC 3052	1968
MCDONALD, DR. J.A. MSC (MAN) PHO (WIS), GEOLOGY DEPT., UNIV. OF SASKATCHEWAN, SASKATOON, SASK. CANADA	1965
MCOONALD V. R HOA HOO FIDM, 41 MALIN ST, KEW, VIC 3101	1968
MCEVEY, A.R. BA, NATIONAL MUSEUM OF VICTORIA, 265 RUSSELL ST., MELBOURNE, VIC 3000	1960
MCKINTY, J.A. MIFA, PO BOX 246, HEALESVILLE, VIC. 3777	1968

MCLAREN, DR. A.C. BSC PHD(CANTAB), PHYSICS DEPT MONASH UNIV., CLAYTON, VIC. 3168	1960
MCLAUGHLIN, DR. R.J.W. MSC PHD(CANTAB), GEDLOGY DEPT., UNIV. OF MELBURN, PARKVILLE, VIC 3052	1963
MCLENNAN, SIR IAN KBE BEE, C/O BHP 300 BOURKE ST., MELBURN, VIC. 3000	1960
MCLISTER, H.D.R., 12 NEFFAN STREET, GLEN IRIS, VIC 3146	1959
MCNALLY, J. MSC, 3 ARCADIA ST., BOX HILL, VIC. 3128	1950
MFOWELL G.J. BSC, 7 OXFORD ST., WENDOUREE, VIC 3355	1965
MENHENNITT THE HON. MR JUSTICE C.I. LL.M., QC, JUDGES CHAMBERS, MELBURN, VIC 3000	1968
MENTHA MRS. I. M. BSC, 22, EMERALD ST., WEST ESSENDON, VIC. 3040	1968
MIDDLETON, W.G.D. AOIPFOR, 81 WIMMERA ST., DIMBOOLA, VIC. 3414	1964
MILLER DR. F.L. BSC PHD MPS, GORDON INST. OF TECHNOLOGY, PO BOX 122 GEELDNG, VIC 3220	1962
MILLER R.H. BSC DIP. ED, THE HAZE, RIOGE ROAD, MOUNT DANOENONG, VIC 3767	1965
MILLER R.N., 42 TIMOR PARADE, HEIDELBERG WEST, VIC 3081	1969
MITCHELL, A. BAGRSC, 6, GRANGE AVE., CANTERBURY, VIC. 3126	1962
MITCHELL A.W.L. BSC, TIMBERTOP, MANSFIELD, VIC. 3722	1946
MITCHELL R.G. DIP JDUR, 21 DUFF ST., SANDRINGHAM, VIC 3191	1968
MOIR, MRS. M.M. MA OIPED, 434 ELGAR RD., BOX HILL, VIC. 3128	1960
MOORE DR. R.R. MSC PHD, C/O MR. G.A. MOORE, 8 SYMONOS ST., HAWTHORN EAST, VIC. 3123	1957
MOORE, K.R., 11 MDNA PLACE, SOUTH YARRA, VIC 3141	1945
MORGAN, D.G. BSC DIPEO, SECONDARY TEACHERS COLLEGE, UNIV. OF MELBOURNE, PARKVILLE, VIC 3052	1959
MORGAN, W.G. RCE, 18, NAN ST., BOX HILL, VIC. 3128	1961
MDRLEY, N.W. BSC BEO MELB, MERCER HOUSE, 11 MERCER RD., ARMADALE, VIC. 3143	1968
MDRRISSON, PROFESSOR J.O. PHD DSC FAA, LA TRDBE UNIVERSITY, BUNDDORA, VIC. 3083	1958
MDSHINSKY N RA LLB, 930 DRUMMOND STREET, NORTH CARLTON, VIC 3054	1968
MDYE, D.G. BSC, 36 SYLVANDER ST., NDRTH BALWYN, VIC. 3104	1967
MUIR MRS. ELAINE P., 487 MOUNT ALEXANDER RD, MDONEE PONOS, VIC 3039	1970
MULVANEY, D.J. MA, DEPT. OF ANTHROPOLOGY, AUST. NAT. UNIV., CANBERRA, ACT. 2600	1957
MURPHY MISS M.T. TPIC, 229 BLUFF ROAD, SANDRINGHAM, VIC 3191	1969
MUSHIN, DR. ROSE MSC PHD, SCHODL OF BACTERIOLOGY, UNIV. OF MELBOURNE, PARKVILLE, VIC 3052	1942
MYER, S. BALLIEU, 2 GRANT AVENUE, TDORAK, VIC 3142	1965
NATHAN J. MA, 5A CAIRNS COURT, BRIGHTON, VIC 3186	1969
NEALES DR. T.F. MA PHO, 45 WHITE AVE., EAST KEW, VIC 3102	1968
NEBOISS, A. MSC, PRES, NATIONAL MUSEUM OF VICTORIA, RUSSELL ST., MELBOURNE, VIC 3000	1957
NELSON DR. J.E. PH.D., DEPT. OF ZOOLOGY, MONASH UNIVERSITY CLAYTON, VIC 3168	1969
NEWMHAM, I.E. MBE MSC, C/O CSIRO, DIV. OF MINERAL CHEMISTRY, P.O. BOX 124, PORT MELBURN, VIC. 3207	1961
NICHOLAS, J.R. BSC BED MACE, 'CHURINGA', INGRAM'S RD., RESEARCH, VIC. 3095	1964
NIELSEN, MISS B.J. MSC, 45 SUMMERHILL RD., GLEN IRIS, VIC. 3146	1954
NOTMAN, G.C. OFC, MT. WIDDERIN, SKIPTON, VIC. 3361	1964
NYE, F.E. BSC, FLAT 2, 18 MURCHISON STREET, EAST ST. KILOA, VIC 3183	1932
NYOEGER, F., 10 GLENHUNTLY RD, ELWOOD, VIC. 3184	1963
DIBRIEN E.J. AGIT, BSC, FRACI, DEPT. OF AGRICULTURE, 5 PARLIAMENT PLACE, MELBOURNE, VIC 3002	1970
O'BRIEN, DR. T.P., 10 PARK RD., MOUNT WAVERLEY, VIC. 3149	1968
OLSEN C.D. BA DIPED, C/O UNESCO, P.D. BOX 5, KABUL, AFGHANISTAN.	1945
OMAN, J.R., 'ROCKBANK', LISMORE, VIC. 3324	1965
O'NEILL, I.C. BCE MENGSCI OIPTRP, 10 MURIEL ST., BURWOOD, VIC. 3125	1965
DPPENHEIM R.C. BSC, ARACI, C/O A.C. ROSE, BOX 10, ALBERT PARK, VIC 3206	1968
PACKARD J.W. NO AGR E. MT AGR E. FTC, 7 ELDER CRT., LDWER TEMPLESDWE, VIC 3107	1969
PAINE, D.W.M. BSCFOR, 17 LODDON ST., BOX HILL, VIC. 3128	1961
PARKER, C.O. BSC DIPBACT (LOND) FRACI, 47 DUTLOOK DRIVE, EAGLEMONT, VIC. 3084	1957
PARRY, DR. R.H.G. BCE MESC PHD, UNIVERSITY ENGINEERING LABS., CAMBRIDGE UNI., CAMBRIDGE, ENGLAND.	1959
PARSDNS, DR. R.F. BSC PHD, BOTANY DEPT, LA TRDBE UNIV, BUNDDORA, VIC 3083	1967



PARTRIDGE A.O. B.SC. HONS,82 KOONDOONA AVENUE,VILLAWOOD,NSW 2163	1969
PASCOE J.R.,YARRA VALLEY C OF E SCHOOL,RINGWOOD,VIC 3134	1968
PAUL V.I. BSC,11 PALM COURT,LOWER TEMPLESTOWE,VIC 3107	1968
PEARCE, T.S. BSC,67 JOHN ST.,ELTHAM,VIC. 3093	1967
PEOOFER DR. A.E.H. MA (CANTAB),INST SEDIMENT & RETROL GEOL., 3303 33RD ST. NW, CALGARY,ALBERTA, CANADA	1965
PEDERICK OR,L.A. DIR,FOR BSC,FOR,RHO,4 INGRAM AVENUE,GLEN WAVERLEY, VIC 3150	1970
PERORIX J.L. FRAS,PO BOX 64,BOX HILL,VIC 3128	1961
PERRIMAN A.E. BSC,CSIRO DIV. CHEMICAL RHYSICS., P.O. BOX 160, CLAYTON,VIC. 3168	1965
PERRY OR. T.M. BA RHO,GEOGRAPHY DEARTMENT,UNIV. OF MELBOURNE, PARKVILLE, VIC 3052	1964
PESCOTT R.T.M. MAGRSC,11 RERPIN ST.,CAMBERWELL,VIC 3124	1944
PETERSON, G.T. PHC FPS,59 EAST BOUNOARY RO.,EAST BENTLEIGH, VIC. 3165	1958
PETERSON OR,J.A. MSC,PHD,GEOGRARHY DEPT.,MONASH UNIV.,CLAYTON, VIC 3168	1968
PHILIP, PROF. G.M. MSC,RHO,DEPT. OF GEOLOGY,UNIV. OF NEW ENGLAND, ARMIDALE, N.S.W. 2350	1955
PIESSE R.D. LLB BA DIP,ED,25 KALONGA ROAD,NORTH BALWYN,VIC 3104	1969
PIZZEY G,CERES,RED HILL,VIC 3937	1968
PLAYFORD, OR. M. MSC RHO(CANTAB),DEPARTMENT OF GEOLOGY, UNIV. OF QUEENSLAND,ST. LUCIA, QLO 4067	1957
POLLITT, J.H. DIR INSTR.,C/O MR. J. FEATHERSTONE,5 BURNIE ST., TOORAK,VIC. 3142	1964
POTTER, SIR W. IAN, BEC,30 SARGOOD ST., TOORAK, 3142	1957
PRESTON, H.E.,47 HAIG ST.,BOX HILL SOUTH,VIC. 3128	1949
PRETTY H.J.C. B.COM.,32 WASHINGTON STREET,TOORAK,VIC 3142	1970
PRYLES M.C. LLM,4 BURNE COURT,KEW,VIC 3101	1968
PURNELL, W.F. FRACI,30 CURRAJONG AVE.,CAMBERWELL,VIC. 3124	1960
RACE, J. MSC,FLAT 2BA,601 ST. KILOA RO., MELBOURNE,VIC. 3004	1961
RARAPORT, RABBI OR. I M.RHIL PHD,63 DOMAIN STREET,SOUTH YARRA, VIC. 3141	1965
RAWLINSON R.A. MSC,SCHOOL OF BIOLOGICAL SCIENCES, LATROBE UNIV BUNDOORA,VIC 3083	1966
RAYNER, J.M. BSC,5 TENNYSON CRESCENT,FORREST, CANBERRA, A.C.T. 2603	1957
READ, T.A. FSTC FRACI MAUSIMM,15 CHATFIELD AVE.,BALWYN,VIC. 3103	1960
REES, DR. A.L.G. OSC PHO FAA, C/O CSIRO,DIV. OF CHEMICAL RHYSICS, P.O.BOX 160, CLAYTON,VIC. 3168	1956
REICHL MRS.P BA HONS OIREO,3 ST.JAMES AVE,MONT ALBERT,VIC 3127	1968
REIO, J.T.,FLAT 5,139 COTHAM ROAD,KEW, 3101	1954
REINSCH O.A. BSC,5 CORNISH ROAD,EAST BURWOOD,VIC 3151	1970
RESCH, DR. C.E. BSC RHO,C/O 16 BOUVIERIE ST.,CARLTON,VIC. 3053	1957
REYNOLDS, L.A. BCE MICE MIE AUST MINSTT,57 RIVERSDALE RO.,HAWTHORN, VIC. 3122	1967
RICHARDS OR,S.M BSC PHO,C/O COMINCO EXPLORATION LTD, 4 GREENHILL ROAD,WAYVILLE,SA 5034	1964
RICHARDSON, OR. J.R. MA PHO,16 RAVEN ST.,KEW.,VIC. 3101	1958
RIGBY, J.F. BSC,2 EDWARD STREET,BRISBANE,QLO 4000	1953
RITCHIE, J.A.,OCEAN GROVE,VIC. 3226	1964
ROBERTS OR,A.M. BSC,MA,PHO.,OEP.T.OF MATHEMATICS, MONASH UNIVERSITY CLAYTON,VIC 3168	1970
ROBERTSON A.G. BF MIE AUST,M.M.B.W.,110 SPENCER ST., MELB., VIC. 3000	1967
ROBINSON DR. G.J.B. MB,BS,FFARACS.,10 SCOTT GROVE,BURWOOD,VIC 3125	1970
ROSENBERG, O.C/O T. NELSON (AUST) LTD.,597 LT. COLLINS ST., MELB., VIC. 3000	1964
ROTHERHAM E.R. FRPS AP3A EFIAP,TILLS DRIVE,WARRANDYTE,VIC 3113	1969
ROUSE DR.J.L. BA MSC RHO A,INST.P FAIP, PHYSICS DEPT,UNIV.OF MELBOURNE,PARKVILLE,VIC 3052	1968
ROWF OR. R.N. BAGSC MSC PHO,23 IRONBARK DRIVE,LOWER TEMPLESTOWE, VIC 3107	1968
ROWE S.F. BSC,GORON INST.OF TECHNOLOGY,PO BOX 122,GEELONG, VIC 3220	1970
ROWLANDS F.J. B.SC B,EO,18 NORWAY AVENUE,BLACKBURN,VIC 3130	1969
ROWNEY, G. BSC,4 RIDOLE ST.,BENTLEIGH,VIC. 3204	1952
SALTER N.V.,13 MERCER ROAD,ARMAOALE, 3143	1968
SANOIE, R.B. BCF MENGSC AMIF AUST,25 MOSELLE ST., MONT ALBERT NORTH.,VIC. 3129	1965



SAUNDERS W.A.J. BSC HONS,224 WARRIGAL RD.,BURWOOD,VIC 3125	1964
SCHLEIGER, N.W. BSC BED,1 ASTLEY ST.,MONTMORENCY,VIC 3094	1949
SCHOFIELD PROF. G.C. MO DPHIL,DEPARTMENT OF ANATOMY, MONASH UNI, CLAYTON,VIC. 3168	1964
SCOTT THE REV.A.J.S. DIP.TH.F.R.MET.S, 14 HAYFIELD ROAD, MOUNT WAVERLEY,VIC 3149	1969
SCOTT, A.R. BE AMIE,10 VEROANT AVE.,TOORAK,VIC. 3142	1958
SCURFIELD, DR. G. BSC PHO,DIVISION OF FOREST PRODUCTS,CSIRO, YARRA BANK RD STH,MLB,VIC 3205	1963
SEEGER R.C.,59 JENKINS ST.,NORTHCOTE,VIC 3070	1946
SEGALL, M.B.,89 MONT ALBERT RD.,CANTERBURY,,VIC. 3126	1968
SEIFFERT M.W. B.AGR,3C,4/73 PARK ST. EAST,BRUNSWICK,VIC 3056	1969
SEITZ MISS P BA,C/O ICIANZ RESEARCH LABS,NEWSOM ST.,ASCOT VALE, VIC 3032	1968
SELBY, B.A. BSC ARACI,19 CHESTERFIELD AVE.,MALVERN,VIC. 3144	1958
SHANKS O.MCK.,23 NESTLE ST.,BENDIGO,VIC 3550	1969
SHEPHERD DR. D.U. MB BS MRACGP MRSH,26 BARODA STREET,ASCOT VALE, VIC. 3032	1969
SHERGOLD DR J.H. PHD,BUREAU OF MINERAL RESOURCES, P.O. BOX 378 CANBERRA,A.C.T. 2600	1967
SHERIDAN MRS.RAE BSC,DIP.EO.,C/O NATIONAL MUSEUM,RUSSELL ST., MELBOURNE,VIC 3000	1970
SIMPENDOORFER K.J. DIPFOR MSCF MIFA,55 MARTIN ROAD,GLEN IRIS, VIC 3146	1968
SIMPSON B.F. BSC ARACI,63 CHAPMAN ST,SUNSHINE,VIC 3020	1968
SIMPSON, H.P.,3 KNUITSFORD ST.,BALWYN,VIC. 3103	1948
SINGLETON, DR. O.P. MSC PHD,GEOLOGY DEPARTMENT,UNIV. OF MELBOURNE, PARKVILLE, VIC 3052	1943
SKINNER, R.G.B. LLB,111 CHARLES ST.,PRAHRAN,VIC. 3181	1960
SKLOVSKY, DR. G.A. INGCHEMISCIL LICSCI INGDON LYONS, 69 PROSPECT HILL RD.,CAMBERWELL,VIC. 3124	1963
SLACK-SMITH, R.J. BSC,7 KINGSTON ST.,SHENTON PARK,W.A. 6008	1960
SMITH, DR. B.J. BSC PHO WALES,NATIONAL MUSEUM OF VICTORIA, RUSSELL ST., MELBOURNE,VIC 3000	1967
SMITH E.HAMILTON DIP,90C,STUD,PO BOX 36,CARLTON SOUTH,VIC 3053	1963
SMITH, DR. L.H. MSC DPHIL FRACI,36 DUKE ST.,KEW,VIC. 3101	1958
SOMERSET, SIR HENRY, MSC MAIMM,C/- A.P.P.M. LTD.,360 COLLINS ST., MELBOURNE,VIC. 3000	1957
SOUTHBY, DR. R. MO FRACP FRACST,FLAT 16,240 DOMAIN RD,SOUTH YARRA, VIC 3141	1965
SPEARS R.F.,49 MENIN ROAD,FOREST HILLS,VIC 3131	1968
SPECHT, PROF.R.L. MSC PHO,BOTANY DEPT.,UNIV. OF QUEENSLAND, ST. LUCIA, QLD 4067	1961
SPENCER J.W. B.SC,42 WHYTE STREET,BRIGHTON,VIC 3186	1969
SPENCER L.B. BSC(HONS),54 GOLOEN WAY,BULLEEN,VIC 3105	1968
SPENCER-JONES, DR. D. BSC PHO,31 WINMALEE RD.,BALWYN,VIC. 3103	1952
STAFF, DR. I.A. MSC OIPED SYD,SCHOOL BIOL. SCIENCES,LA TROBE UNIV., BUNDOORA,VIC. 3083	1967
STELLA A.R. BARCH ARI8A,6 ARGYLE PLACE,NORTH CARLTON,VIC 3053	1968
STEVENS, B.J.M.,6 JENNINGS ST.,SANORINGHAM,VIC. 3191	1961
STEWART, DR. A.J. MSC, PHD,BUREAU OF MINERAL RESOURCES, P.O. BOX 378, CANBERRA CITY,ACT 2601	1961
STOVER DR.L.E. BSC,PHD,FGS AMER,ESSO STANDARO OIL AUST LTD, GPO BOX 4047 SYDNEY,NSW 2001	1970
STRAUSS, DR. W.,9 MOORE ST.,HAWTHORN,VIC. 3122	1968
STREET, PROF. R. MA PHO LOND,17 HOWIE ST.,GLEN IRIS,VIC. 3146	1965
STRUSZ, DR.D.L. BSC PHO,97 BURNIE ST.,LYONS,A.C.T. 2606	1966
STYLES, D.F. MBE BSC AMIE AUST,14 JOHN STREET,BLACKBURN,VIC. 3130	1958
SULLIVAN, W.,37 STRATHALLAN RD.,MACLEOD,VIC. 3085	1943
SUTTON, DR. P.R.N. DOSC LDS,24 WELLINGTON ST.,BRIGHTON,VIC. 3186	1959
SWAN PROF. J.M. PHO DSC FAA FRACI,28 THE RIDGE,CANTERBURY,VIC 3126	1968
TAFT DR. B. MB BS OOR MCRA,116 RIVERSDALE ROAD,CAMBERWELL,VIC 3124	1968
TATTAM PROF.C.M. PHO DSC,7 ALBERT JONES COURT,EAGLEMONT,VIC 3084	1945
TAYLOR, O.J. MSC,GEOLOGY DEPT., SYDNEY UNIV.,SYDNEY,N.S.W. 2006	1961
TAYLOR J.I. DIP.ARCH ARI8A,5 HIGH STREET,REAUMARIS,VIC 3193	1968
TAYLOR M.W.,44 IRELAND AVENUE,WANTIRNA SOUTH,VIC 3152	1969
TAYLOR MISS N.,FLAT 4, ERNA COURT,181 RIVERSDALE RD. HAWTHORN, VIC 3122	1969
TEMPLE, P.,7 MONASH ST.,ASCOT VALE,VIC. 3032	1962
TENNI P.B. BSC AMIE,641 CANTERBURY ROAD,VERMONT,VIC 3133	1968

TERNMOUTH, S.T. BSC DIPED, 5 KANDOKA AVE., LOWER TEMPLESTONE, VIC. 3107	1957
TEX, PROF. E. OEN PHD(LEYDEN), C/O GEDL. MIN. INST. R.U.V., LEIDEN ST. U., GARENMARKT 18, LEYDEN, HOLLAND	1952
THOMAS, F.J.O. BSC HONS ARCS, I.C.I.A.N.Z., BIDL. RESEARCH STN., CROYDON, VIC. 3136	1955
THOMAS, OR. G.A. BSC PHD, GEOLOGY DEPT., MELB. UNIVERSITY, PARKVILLE, VIC. 3052	1944
THOMAS, H.F., P.O. BOX 78, IRYMPLE, VIC. 3498	1961
THOMPSON B. BSC, DEPT. OF MINES, 107 RUSSELL ST MELBOURNE, VIC 3000	1963
THOMPSON, G.O. AMIE AUST HON. MIBF, 4 BROOKS PLACE, YARRAVILLE, VIC 3013	1959
THOMPSON, G.T., UNIT 8, HARANDA COURT, 8 PARRING RD., BALWYN, VIC 3103	1953
THOMPSON MISS F.E. BA ALAA, FLAT 5 24 MASON STREET, HAWTHORN, VIC 3122	1968
THOMSON OR J.A. MSc PHD, GENETICS DEPT., UNIV. OF MELBOURNE, PARKVILLE, VIC 3052	1958
THORN, W. MEE MIE AUST, 9 FLORENCE AVE., KEW, VIC. 3101	1958
THORPE F.J., 10 LOVELL STREET, HAWTHORN, VIC 3123	1970
TIMCKE, E.W., 15 FAIRCROFT AVE., GLEN IRIS, VIC. 3146	1950
TOWNSEND, PROF. SIR LANCE, MD MS FRCS(EOIN), UNIVERSITY OF MELBOURNE, PARKVILLE, VIC. 3052	1957
TURNER, PROF. J.S. MA PHD MSc FAA, BOTANY DEPT, UNIV. OF MELBOURNE, PARKVILLE, VIC 3052	1938
TYLEE, A.N., SIMSONS RD., LARONER, VIA WARRAGUL, VIC. 3821	1951
UHL, A.H. MIE AUST MIEE LOND MAIEE NY, 1 GWENOA AVE., BLACKBURN, VIC. 3130	1964
VALE, W.H., 17 WALSTAB ST., EAST BRIGHTON, VIC. 3187	1961
VASEY MRS.F.R. BSC (MELB), PUCKS HOLLOW, FERNY CREEK, VIC 3786	1968
VAUGHAN OR. G.N. PHO MSc, 'INGLESBY', UPPER REACONSFIELD, VIC 3808	1969
VERSO, OR. M.L. MB BS OTMH MCPA, BLODO BANK, 114 FLINDERS ST., MELBOURNE, VIC. 3000	1962
WADE OR. MARY BSC PHD, DEPT. OF GEOLOGY, UNIV. OF ADELAIDE, SA 5001	1970
WAUGHAM, PROF. SIR SAMUEL MA LLO AGROIP, 220 PARK ST., WEST BRUNSWICK, VIC 3055	1932
WAKEFIELD, N.A. MSc, MONASH TEACHERS COLLEGE, CLAYTON, VIC 3168	1961
WAGOROP, PROF. A.B. MSc (TAS) PHD(LEEDS) OSC(MELB), 3 GWENOA AVE., BLACKBURN, VIC. 3130	1968
WARK SIR IAN W. CMG, CBE, PHD, DSC, FAA, 31 LINUM STREET, BLACKBURN, VIC 3130	1961
WARK, OR. J.MCF. CBE DOSC, 117 YARRANBAT AVENUE, BALWYN, VIC. 3103	1966
WARNEKE R.M. BAGRSC MSc, FISHERIES & WILDLIFE DEPT., 605 FLINDERS ST., MELBOURNE, VIC 3000	1967
WARREN G.T., 40 JONES COURT, ROSANNA, VIC 3084	1968
WARREN, PROF. J.W. MA PHD, ZOOLOGY DEPARTMENT, MONASH UNIVERSITY, CLAYTON, VIC. 3168	1963
WASS J.H., 113 NICHOLSON STREET, EAST COBURG, VIC 3058	1969
WATSON, G.F., ZOOLOGY DEPARTMENT, MELB. UNIVERSITY, PARKVILLE, VIC. 3052	1968
WATSON, MRS. J. ASMB AMTC, 74 NIMMO ST., FOSSENOON, VIC. 3040	1961
WEBB A.W.F. M.Sc FOR. OIP FOR OXON, 5 GRENVILLE ST., BOX HILL, VIC 3128	1969
WEBB G.C. BSC DIPED MELBOURNE, 47 FORTUNA AVE, NORTH BALWYN, VIC 3104	1968
WEICKHART, L.W. MSc FRACI, 125 CANTERBURY RD., CANTERBURY, VIC. 3126	1959
WELLS, DR. R.J.H. BVSC PHD, CAMERDN LODGE, COWPER AVENUE MT. MACEDON, VIC 3441	1965
WEST, A.L. BA DIPSOCSTUD, 17 THE RIDGE, KNOXFIELD, VIC. 3180	1967
WESTE MRS.G. MSc, 29 GILBERT GROVE, BENTLEIGH, VIC 3204	1968
WETTENHALL, OR. H.N.B. MD BS MRCP FRACP, 41 SPRING ST., MELBOURNE, VIC. 3000	1959
WHARTON, J.C.F. BSC, 10 RAYMOND ST., ASHWOOD, VIC. 3147	1967
WHITBY L.R. AASA ACIS, 55 WINGATE STREET, BENTLEIGH EAST, VIC 3165	1968
WHITE, PROF. M.J.O. OSC LOND FRs FAA, GENETICS DEPARTMENT, MELB. UNIVERSITY, PARKVILLE, VIC. 3052	1958
WHITE, R.K. FPAA, 414 COLLINS ST., MELBOURNE, VIC. 3000	1958
WHITELAW, J.J. BME, 286 HUNTINGDALE RD., CHAOSTONE, VIC. 3148	1963
WHITER, H.R., 13 ANDERSONS RD., EAST HAWTHORN, VIC. 3123	1967
WHITING, R.G. BME, 3 PARKSIDE AVE., BALWYN, VIC. 3103	1959
WILCOCK, A.A. BSC BED, GEOGRAPHY DEPARTMENT, MELB. UNIVERSITY, PARKVILLE, VIC. 3052	1934



WILKINSON H.E. BSC, HILL VIEW, WIRTH STREET, BENOIGD, VIC 3550	1963
WILLIAMS C.M. AASA, 4 OLINDA AVENUE, BEAUMARIS, VIC 3193	1968
WILLIAMS T.W., 90 STUOLEY RD., IVANHOE, VIC 3079	1969
WILLIAMS DR. W.O. PH.D. ZOOLOGY DEPT, MONASH UNIV., CLAYTON, VIC 3168	1969
WILLIS, A.G. MSC, ZOOLOGY DEPARTMENT, MELB. UNIVERSITY, PARKVILLE, VIC. 3052	1949
WILLIS J.H. BSC, 102 HALE ST, BRIGHTON, VIC 3186	1964
WILSON, D. BSC, 46 HOODLE ST., ESSENOON, VIC. 3040	1961
WINSTON R. F. INST O M, INST M, 91 GRANGE ROAD, TDORAK, VIC 3142	1969
WISE J.H. BA, OIP, ED, 16 BORONIA STREET, DAKLEIGH SOUTH, VIC 3167	1969
WONG N. MSC, GEOLOGICAL SURVEY OFFICE, KOTA KINABALU, MALAYSIA	1968
WOOD HISS C.M. BA, MACE, 4A GLENRDY ROAD, HAWTHORN, VIC 3122	1970
WOODFORD, E.R., 40 ROSE ST., HCKINNDN, VIC. 3204	1963
WOODRUFF, O.S. BSC, BIOLOGICAL LABS., 16 DIVINITY AVE., HARVARD U., CAMBRIDGE, MASS., USA 02138	1965
ZEIDLER D.R. B.SC., 2A GRANGE AVENUE, CANTERBURY, VIC 3126	1970

## ASSOCIATES

AUTRY W.C. BSC, P.O. BOX 58354, HOUSTON TEXAS U.S.A., 77058	1957
BAKER A.A., P.O. BOX 164, MORNINGTON, VIC. 3931	1946
BALDWIN J.G. BSC BAGRSC, 33 WALNUT AVE., MILDURA, VIC. 3500	1949
BAMFORD, W.E. BE (HONS), 352 DANKS STREET, MIDOLE PARK, VIC. 3206	1963
BAUM F.T., 1 BERYL ST., NUNAWADING, VIC. 3131	1967
BEAVIS MRS. J.H., P.O. BOX 67, CLAYTON, VIC 3168	1965
BISHOP J.J. BA, HIGH SCHOOL, MOE, VIC 3825	1950
BDOCH P.E. BSC, 32 SWAY FIELO RD., MT. WAVERLEY, VIC 3149	1957
BOLLEN P.W., 5 MERCER RD., ARMADALE, VIC 3143	1957
BODURKE D.O.N., 141 SOUTH RD., BRIGHTON, VIC. 3186	1964
BOWEN K.G. BSC, 2 BURKE ST., MONTMORENCY, VIC. 3094	1964
BOWLER J.M. HSC, DEPT. OF GEOGRAPHY, INST. OF ADV. STUD., A.N.U., CANBERRA, ACT 2600	1960
BURN R., 3 NANTES ST. NEWTOWN, GEELONG, 3220	1956
BURNS O. S., 11 ROBERTSON ST., COLAC, VIC 3250	1960
BUTTERY S. H., 15 JUDITH COURT, MT. WAVERLEY, VIC 3149	1952
CARR MRS. O. J. MSC, RES. SCHL. BIOL. SCIENCES, A.N.U., P.O. BOX 4, CANBERRA, ACT 2600	1937
CARTER A.E., 12 BERTRAM ST., BURWOOD, VIC 3125	1968
CARTER DR. A. N MSC PHO, 8 SCOTT ST., MAROUBRA, NSW 2035	1947
CLARKE W. G. BE BSC DIPFD, 2 MEES CRESCENT, FAULCONBRIDGE, NSW 2776	1957
CLIFFORD DR. H. T. MSC PHO, BOTANY DEPT. QUEENSLAND UNI., ST. LUCIA, QLD. 4067	1949
CDBRETT A. M., 4 OXFORD CLOSE, MODRABRIN, VIC. 3189	1951
CDCHRANE G.W. MSC, 8 CROWN AVENUE, MOROIALDC, VIC 3195	1945
COLLEGE MISS J.S., 51 THROUGH RD., BURWOOD, VIC. 3125	1964
CORMACK, M.G., LWR. CRAWFORD PTE. BAG 39, HEYWOOD, VIC. 3304	1961
CDUPER, JAMES K. FRMIT, C/O R.HARE & ASSOCIATES, 18 LITTLE COLLINS ST., VIC. 3000	1965
CDURT, A.B. BSC, NATIONAL HERBARIUM, SOUTH YARRA, VIC. 3141	1949
COVENTRY, A.J., NATIONAL MUSEUM OF VICTORIA, RUSSELL ST. HELDBURNE, VIC 3000	1966
DAVIES, A.F., WAYSIDE DEL BRIDGEWATER RD., PORTLAND, VIC. 3305	1965
DE JONK, B.T.R., 21 HALL COURT, BLACKBURN, VIC. 3130	1964
DICKINS DR. J. HCG. HSC, PHD., BUREAU OF MINERAL RESOURCES, CANBERRA, A.C.T. 2600	1952
ELHORE, L.K.H., P.O. BOX 317, HAMILTON, VIC. 3300	1964
ENGLISH, J.R., 302 LOWER HEIOELBERG RD., EAST IVANHOE, VIC. 3079	1956
FINLAY MISS C.J BSC, GEDLOGY DEPT, UNIV. OF MELBOURNE, PARKVILLE, VIC 3052	1958
FISHER, DR. EILEEN E. PHD, 1 BALWYN RD., CANTERBURY, VIC. 3126	1949
FORREST, J.M., METROPOLITAN FARM, WERRIBEE, VIC 3030	1954
FROSTICK, A.C., 12 POWER ST., NORTH WILLIAMSTOWN, VIC. 3016	1933
GAMBLE O.S., 51 GROVE RD., HAWTHORN, VIC 3122	1964
GOSTIN DR. V.A. HSC, PHD, DEPT. OF GEOLOGY, ADELAIDE UNIV, ADELAIDE, SA 5001	1963
HATTON, H., 55 HUNT CRESCENT, ASCOT VALE, VIC. 3032	1965
HILL PROF. DOROTHY CRE, OSC, PHD, FAA, DEPT. GEOLOGY, UNIV. QUEENSL, ST. LUCIA, QLD 4067	1939



HOPE MRS. J. BSC, C/O DEPT. BIOGEOG. SCH. PACIFIC 3, ANU BOX 4 CANBERRA, ACT 2600	1967
HOUNSLOW DR. A.W. FRMTC BSC PHO, DEPT. OF GEOLOGY, IDAHO STATE UNIV. POCA TELLO, IDAHO, USA 83201	1958
JOHNS DR. M.W. BSC MB BS, 12 ELLISON STREET, EAST MALVERN, VIC 3145	1958
JONES B.C. MA, LLB, ACTT, 24 PUROY AVENUE, OAKDENONG, VIC 3175	1965
KENLEY, P.R. BSC, 14 YARRABEE COURT, MT. WAVERLEY, VIC. 3149	1948
KERSHAW R.C. BSC, 45 WEST TAMAR RD., LAUNCESTON, TAS. 7250	1956
LAWRENCE, C.R. BSC, 4 UNA ST., MT. WAVERLEY, VIC. 3149	1958
LEARMONTH, A.P., 12 CORNWALL RD., SUNSHINE, VIC. 3020	1955
LIM MRS. ELAINE M. BSC, PRIVATE BOX 5405CC, GPO MELBOURNE, VIC 3001	1967
LINCOLN, J.O.E., 11 CRATLOE ROAD, MOUNT WAVERLEY, VIC 3149	1952
MARSDEN, M.A.H. BSC, GEOLOGY DEPT., UNIV. OF MELBOURNE, PARKVILLE, VIC 3052	1952
MATTHAEI MRS. G BA OIPED, 146 GATEHOUSE ST, PARKVILLE, VIC 3052	1959
MCLAURIN, A.N., COUANGALT, VIA GISBORNE, VIC. 3437	1963
MOONEY, M.J., OOUTHIE ROAD, SEVILLE, VIC 3139	1963
MOORS, DR. H.T. PHD, BSC, 27 ROSEDALE RD., GLEN IRIS, VIC 3146	1965
NEILSON, J.L. BSC, 55 GLYNDON RD., CAMBERWELL, VIC. 3124	1952
NETHERWAY G.C., 606 OANA ST., BALLARAT, VIC. 3350	1958
NICHOLSON B.M. BAGRSC, SOIL CONSERVATION AUTHORITY, 32 PYKE ST. BAIRNSDALE, VIC 3075	1963
NIKSIC N. ARACI, DIPENG ZAGREB, 5 VAUGHAN AVE., CANTERBURY, VIC 3126	1966
PASSIURA, DR. J.B., CSIRO. DIV. OF LAND RESEARCH, P.O. BOX 109 CANBERRA, A.C.T. 2601	1961
PATON R.J., 295 DORSET RD, BORONIA, VIC 3155	1968
PAYNE T.E.N., WOODBURN, KILMORE, VIC. 3601	1945
PICKEN I.O., 20 PACKINGTON ST., KEW, VIC. 3101	1967
PINCHES MRS. M., 25 GREENHILLS AVE., MONTROSE, VIC. 3765	1943
POOLE I.R., 27 GLEN EBOR AVE., BLACKBURN, VIC. 3130	1966
PRETTY R.B. BSC, PRIVATE MAIL BAG 7C, COBARGO, N.S.W. 2547	1922
RASH, K.E., 519 HUMFFRAY STREET, BALLARAT, VIC. 3350	1960
RAWLINS R.J. BSC, PO BOX 3644, DARWIN, N.T. 5794	1957
REED DR. K.J. BSC, MS, PHO, GULF RES. & DEV. CO., PO DRAWER 2038, PITTSBURGH, PENNSYLVANIA, USA 15230	1958
RIMINGTON K.N. BSC, 27A GORON STREET, HAMPTON, VIC 3188	1948
ROWE R.K. BSC. FOR, 17 BROOY ST., WANGARATTA, VIC. 3677	1965
SEARLE S.S., METROPOLITAN FARM, WERRIBEE, VIC. 3030	1954
SEERECK J.H. BSC, WARRAWONG, ERITH LANE, KALORAMA, VIC 3766	1967
SHAK H., 16 DOUGLAS AVE., BOX HILL SOUTH, VIC. 3128	1956
SHERRARD MRS. H.M. MSC, 43 ROBERTSON RD., CENTENNIAL PARK, SYDNEY, N.S.W. 2021	1918
SIMPSON B., 3 KNUSTFORD ST., BALWYN, VIC. 3103	1959
SIMPSON K.G., 27 KINGSWOOD DRIVE, DINGLEY, VIC 3172	1967
SINKOTT P.J., 17 NORMDALE RD., EAST BENTLEIGH, VIC. 3165	1959
STONE DR. I.G. MSC. PHO., 24 ALANDALE RD., EAGLEMONT, VIC 3084	1965
STONE, A.G., 24 ALANDALE RD., EAGLEMONT, VIC. 3084	1965
STUBBS D., 2 COLERIDGE ST., ELWOOD, VIC. 3184	1960
TAYLOR T.W. MSC, BOX 7, CLONCURRY, QLO 4824	1961
TUDDENHAM W.G. BSC OIP, EO, SCHOOL OF FORESTRY, UNIV. OF MELBOURNE, PARKVILLE, VIC 3052	1963
VANDENBERG A.H.M., 6 FREW AVE., FRANKSTON, VIC. 3199	1965
VAN MEURS W., 10 WATTA ST., BOX HILL, VIC 3128	1969
VASFY G.H. BCE, MELBOURNE UNIVERSITY, PARKVILLE, VIC 3052	1936
WALKER DR. A.L., C/O A.V. JENNINGS (AUST) LTD., 690 SPRINGVALE RD., MULGRAVE, VIC 3170	1961
WHITE O.L. BSC MASC, CIVIL ENG DEPT WATERLOO UNIV., WATERLOO, ONTARIO, CANADA.	1955
WHITEHEAD MRS. S. MSC, C/O AUST. MINERAL DEV. LTD., FREWVILLE, SA 5063	1942
WILLIAMS MRS. V.M., CARRAMAR, SHE OAKS VIA BANNOCKBURN, VIC 3331	1962
WYMOND A.P. MSC, OIV. FOREST PRODUCTS CSIRO, P.O. BOX 18 SOUTH MELBOURNE, VIC. 3205	1951

# Royal Society of Victoria

## REPORT OF THE COUNCIL FOR THE YEAR ENDING 11 MARCH 1971

The Council presents to Members of the Royal Society of Victoria its report on the activities of the Society during its 116th year.

**COUNCIL**—The following Office-bearers and Councillors were elected at the Annual General Meeting on 12th March, 1970.

*President:* Mr E. D. Gill

*Vice-Presidents:* Mr A. Dunbavin Butcher, Mr L. Adams

*Immediate Past President:* Dr P. G. Law

*Honorary Treasurer:* Professor J. D. Morrison

*Honorary Librarian:* Dr J. G. Douglas

*Honorary Secretary:* Professor A. B. Wardrop

*Honorary Editor:* Professor J. W. Warren

*Honorary Research Secretary:* Professor M. J. Canny

*Honorary Development Manager:* Dr G. A. Sklovsky

**Council—**

Dr G. D. Aitchison

Sir Robert Blackwood

Dr A. G. Brown

Mr J. H. Chinner

Mr H. C. Chipman

Mr G. A. Kaufmann

Professor J. F. Lovering

Mr A. E. Perriman

Dr D. Spencer-Jones

Professor J. M. Swan

The resignation from Council of Dr B. D. Cuming was accepted with regret.

Mr N. W. Morley was elected *Hon. Assistant Secretary* on 14th May.

**COMMITTEES OF COUNCIL.** The following Committees met during the year: Development, Publications, Library.

**MEETING AND LECTURES.** During the year, ten Ordinary, and one Special meeting, were held.

**MARCH 12**—‘The Geology of the Moon’, by Professor J. F. Lovering.

**APRIL 9**—‘Drifts from Science in Australian Education’, by Professor P. J. Fensham.

**MAY 14**—Medal Lecture ‘Financing Health Service Expenditures’, by J. S. Decble and R. B. Scotton.

**JUNE 11**—‘Electron Microscopy’, by J. L. Farrant.

**JULY 9**—Research Papers. ‘The Fossil *Zenatiopsis ultima*’, by T. A. Darragh. ‘The Stromatoporoid genera *Actinostroma* and *Nexililamina*’, by C. W. Mallett. ‘The Disappearing Mitchell Delta’, by N. L. Rosengren (with E. C. F. Bird).

**AUGUST 13**—‘Age and Cancer’, by Sir Macfarlane Burnet.

**SEPTEMBER 1**—Special Joint Meeting with the Anthropological Society of Victoria and the Archaeological Society of Victoria. ‘The Last of the Tasmanian Aborigines. Excavations on Flinders Island, 1970’, by Miss J. Birmingham.

**SEPTEMBER 10**—‘Human Engineering’, by R. W. Cumming.

**OCTOBER 8**—Presidential Address. ‘The Far-reaching Effects of the Ice Age Sea-level Changes on the Flat Continent of Australia’, by E. D. Gill.



NOVEMBER 12—Soiree. Film 'A Long Shot that Paid Off'. 'Aspects of the Society's History', by R. T. M. Pescott. Exhibits by Department of Fisheries and Wildlife; National Museum; Botany Department, La Trobe University; ICIANZ Ltd.

DECEMBER 10—Research Papers. 'Study of Mammal Remains from Pyramids Cave and Wombeyan Caves', by N. A. Wakefield. 'The occurrence of Reaction Fibres in *Xanthorrhoea australis*' by I. A. Staff.

Attendances at Ordinary Meetings of the Society totalled 830.

## ANNUAL REPORT

MEMBERSHIP—During the year thirty new Members were admitted to the Society. Eleven resignations were accepted, and one member was removed.

Membership at 28th February was: Honorary Life Members 2; Life Members 26; Members 477; Associates and Country Members 90. Total: 597.

Council recorded with deep regret the deaths of Dr F. Bage, Mr H. L. Buckingham, Mr F. G. Elford (for many years Honorary Assistant Editor of *Proceedings*), Miss F. V. Murray, Dr R. G. Orr and Professor D. F. Thomson.

ANNA FREDERICA BAGE was born in Melbourne, and graduated M.Sc. in Biology in that University. After spending five years as research worker and demonstrator under Sir Baldwin Speneer, and two years in research at King's College, London, she was appointed Lecturer in Biology in the University of Queensland in 1913, and the following year she became the first Principal of the Women's College, a position she held until her retirement in 1946. She was the first woman to be elected a Member of the Senate of Queensland University in 1923, and she held that position until 1949. In 1951 the honorary degree of Doctor of Laws was conferred on her, and she was an Officer of the Order of the British Empire and a Fellow of the Linnaean Society of London. On two occasions she was a Substitute Delegate for Australia to the League of Nations. She was active in many women's organizations.

Dr Bage joined the Society in 1906, and published papers in *Proceedings* in 1908 and 1910. She died in Brisbane in October 1970.

FRANCIS GORDON ELFORD was born in 1907 and died on 18th June 1970. He was educated at Ballarat High School and the University of Melbourne, where he graduated B.Sc. and Dip.Ed., majoring in biology and geology. After teaching at Ballarat and then on the Teachers' College staff at Melbourne he resigned to take charge of the Ornithology Department at the National Museum in 1946. In 1948 he joined the Registrar's staff at the University of Melbourne as Secretary to the Scientific and Medical Faculties, and was at his work on the day when he died of a heart attack.

He was a member of the Society from 1929 until his death, and was Assistant Editor of the *Proceedings* from 1955 until 1966. His University duties were heavy, but he carried out his editorial task with the thoroughness and attention to detail that typified him, though the bulk of published papers increased greatly during his term of office.

FLORENCE (FAY) VIVIENNE MURRAY was born in Gormanston, Tasmania, in 1908. Her father was General Manager of the Mount Lyell copper mine for 25 years, and her brother Hugh later occupied the same position. She was educated in Melbourne at Fintona and at the University, where she gained the degree of M.Sc. and worked as a demonstrator. In 1936 she joined the library staff of CSIR (now CSIRO). In 1964 physical disabilities forced retirement, but with fortitude she continued her zoological researches until her death on September 12th 1970. She published twelve zoological papers. In recent years, her main research has been on the breeding and embryology of Victorian molluscs. She joined the Society in 1964.

DONALD FINLAY FERGUSSON THOMSON was born in Melbourne and educated at Scotch College and the University of Melbourne, where his major studies were in Zoology and Botany. In field expeditions he carried on the tradition set by Sir Baldwin Spencer as an anthropologist concerned mainly with the Australian aboriginal. He was awarded the Syme and Harbison-Higinbotham Prizes, and was the first holder of a Diploma in Anthropology in Australia. He was for many years a Research Fellow in the University of Melbourne, and he held a personal chair in Anthropology from 1964 until his retirement in 1968. His distinctions included D.Sc., (Melbourne), Ph.D. (Cambridge) Diplomas of Anthropology (Sydney and Cambridge) and O.B.E. He became a Member of the Society in 1958, contributed papers to *Proceedings* and lectured to the Society on his expedition to the Bindibu tribe of aborigines. He died in May, 1970.



Professor Thomson was recognized internationally as the great authority on the native people of Australia. He travelled thousands of miles in the most difficult outback country, making friendly contacts with the survivors of aboriginal tribes, studying their culture and collecting their artefacts.

**TRUSTEE**—The Governor-in-Council has appointed Sir Henry Somerset, C.B.E., as a Trustee for the Society in the place of the late Mr A. R. L. Wiltshire.

**CONGRATULATIONS**—Council extends its congratulations to Sir Lance Townsend, Professor Dorothy Hill, C.B.E. and Dr R. H. Laby, M.B.E., who were honoured by Her Majesty the Queen at the New Year.

**PROCEEDINGS**—During the year the Society published Volume 83, Part 2 of *Proceedings* at a cost of \$4786. Publication of Volume 84, Part 1 has been unavoidably delayed until April 1971. Council acknowledges with gratitude contributions towards the cost of publication from the Government of Victoria, the University of Melbourne and the Australian National University.

**LIBRARY**—2583 volumes and parts were received during the year, mainly from exchanges with 62 Australasian and 274 overseas organizations. 510 items were borrowed from the Library (453 in 1969). Additional shelving has been installed in the ground floor stack room. During the year, \$64 was contributed by Members towards the cost of binding, and 56 volumes were bound at a cost of \$197.

**HALL**—In addition to the Society and the R.C.O.G., 15 professional and other bodies held 65 meetings on the premises, compared with 70 in 1969. Repairs and improvements were carried out during the year at a total cost of \$429.

**FINANCIAL STATEMENT**—The Society's present surplus is due mainly to the delay in publishing Vol. 84, Part 1 of *Proceedings*.

The increase of the State Government's grant from \$1600 to \$3000 per year is gratefully acknowledged. Interest on investments has been increased by re-investment from \$3121 to \$4521 per annum.

Sales of publications in 1970 were \$3286, compared with \$5081 in 1969.

Many persons and organizations have assisted the Society during the year, and Council, on behalf of the Society, expresses its thanks to them: Sir Ian Potter (Hon. Financial Adviser), Mr T. C. Boehme (Hon. Auditor), Mr F. Suendermann, on behalf of Sir Roy Grounds (Hon. Architect), Phillips Fox and Masel (Hon. Solicitors), the Parks and Gardens Department of the Melbourne City Council, and Mr and Mrs A. Sadik.

This Report has been accepted by Council for submission to the Annual General Meeting on 11th March, 1971.

E. D. GILL,

President

## BALANCE SHEET AS AT 31st DECEMBER, 1970

LIABILITIES		ASSETS	
1969		1969	
\$163,094	Accumulated Funds at 1/1/70	\$85,500	Building
835	Add Surplus of Income	51,245	Debentures at cost (face value \$52,200)
		10,644	Shares (at cost)
\$163,929		11,448	Stock of Publications at 31/12/70
89	Creditors	3,255	National Bank of Australasia
101	Subscriptions in Advance	800	Office Furniture and Machines—at written down value
		642	Subscriptions in Arrears
		585	Sundry Debtors
		—	Loans—Portview Nominees @ 6%
		—	Tricontinental Corporation Ltd. @ 6% on call
\$164,119		\$164,119	
		\$170,758.75	
			\$85,500.00
			51,719.90
			10,758.00
			11,756.00
			1,139.70
			664.00
			769.50
			451.65
			5,000.00
			3,000.00
			\$170,758.75

I report that I have conducted an Audit of the Books of Account and Records of the Royal Society of Victoria for the year ended 31st December, 1970, and have prepared the Income and Expenditure Account for that year and a Balance Sheet as at 31st December, 1970.

In my opinion the Statement of Income and Expenditure correctly records the transactions of the Society during the period ended 31st December, 1970, and the Balance Sheet exhibits a true and fair view of the financial position of the Society as at that date. I have also examined the Registers of the Society including that of the members and find them to be in order.

I have received all the information and explanations which from time to time I have required from the Executive Officer (Dr. R. R. Garran) and have accepted his figure for the value of the stock of *Proceedings* on hand at balance date.

(Signed) T. C. BOEHME, F.C.A.

Honorary Auditor

## STATEMENT OF INCOME AND EXPENDITURE FOR THE YEAR ENDED 31st DECEMBER, 1970

INCOME		EXPENDITURE	
1969		1969	
Benefactions	\$814.00	Depreciation—Furniture and Fittings	\$74.00
Grants	3,950.00	Electricity	642.77
Interest Received	4,521.52	Hall Keeping Costs	648.00
Profit on Sale of Shares	—	Insurance	434.86
Publication Sales	3,286.28	Printing and Stationery	641.75
Rents Received	1,481.29	Publishing <i>Proceedings</i>	5,472.89
R.C.O. & G. Repayments	443.69	Postage	647.20
Refunds	338.79	Repairs and Maintenance	428.58
Sundry Receipts	17.35	Rates (M.M.B.W.)	47.63
Subscriptions	5,791.19	Salaries	3,888.00
Stock of <i>Proceedings</i> at 31/12/70		Sundry Expenses	463.61
At Cost	\$5,836.00	Telephone	133.40
At Valuation	5,920.00	Stock of <i>Proceedings</i> at 1/1/70	\$5,517.00
		At Cost	5,931.00
		At Valuation	
		Meeting Expenses	11,448.00
		Surplus Income	683.13
			6,746.29
			\$32,400.11
\$32,204	\$32,400.11		

(Signed) LIONEL ADAMS  
Acting Hon. Treasurer



SCHEDULE OF SECURITIES AND INVESTMENTS AT 31st DECEMBER, 1970

ORDINARY SHARES			Fully Paid to	No. Held	Probate Value	DEBENTURES			
	Type						Int. Rate	Face Value	Maturity
Australian Foundation Investment Co. Ltd.	Ord.		50c	1,000	1,160	Australian Guarantee Corp. Ltd.	8%	\$100	30/9/75
Australian Foundation Investment Co. Ltd.	Ord.		50c	100	Bonus Issue	Finance Corporation of Australia Ltd.	7½%	200	31/12/72
Australian & Kandos Cement Holdings Ltd.	Ord.		50c	1,000	1,220	Eso Standard Oil (Aust.) Ltd.	8%	3,300	31/10/75
Dunlop Australia Ltd.	Ord.		\$1	1,000	1,850	Commonwealth Industrial Gases Ltd. Repco Ltd.	7½%	4,000	31/7/78
Dunlop Australia Ltd. (new issue at cost)	Ord.		\$1	1,000	1,850	Australian Paper Manufacturers Ltd. Containers Ltd.	7½%	10,000	30/3/79
Email Ltd.	Ord.		50c	142	142	Carlton & United Breweries Ltd.	8%	1,500	30/4/79
Elder Smith Goldsbrough Mort Ltd.	Ord.		\$2	500	355	Blue Metal Industries Ltd.	7½%	8,000	30/4/82
National Bank of Australasia Ltd.	Ord.		\$1	824	1,730	Mercantile Credits	8½%	4,000	31/5/84
Dunlop Australia Ltd.	Ord.		50c	1,250	3,787	John Lysaght (Aust.) Ltd.	9%	2,000	30/6/80
				228	114	Myer Emporium	9%	400	28/2/79
							8%	2,000	31/10/90
								47,500	31/3/90
PREFERENCE SHARES					10,358	UNSECURED NOTES			
Associated Dairies Ltd.	7% Cum. Pref		\$2	200	400	General Motors Acceptance Corporation	7½%	4,700	30/9/77
								\$52,200	
As per Balance Sheet					\$10,758	DEBENTURES—Per Balance Sheet at Cost		\$51,719.90	

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